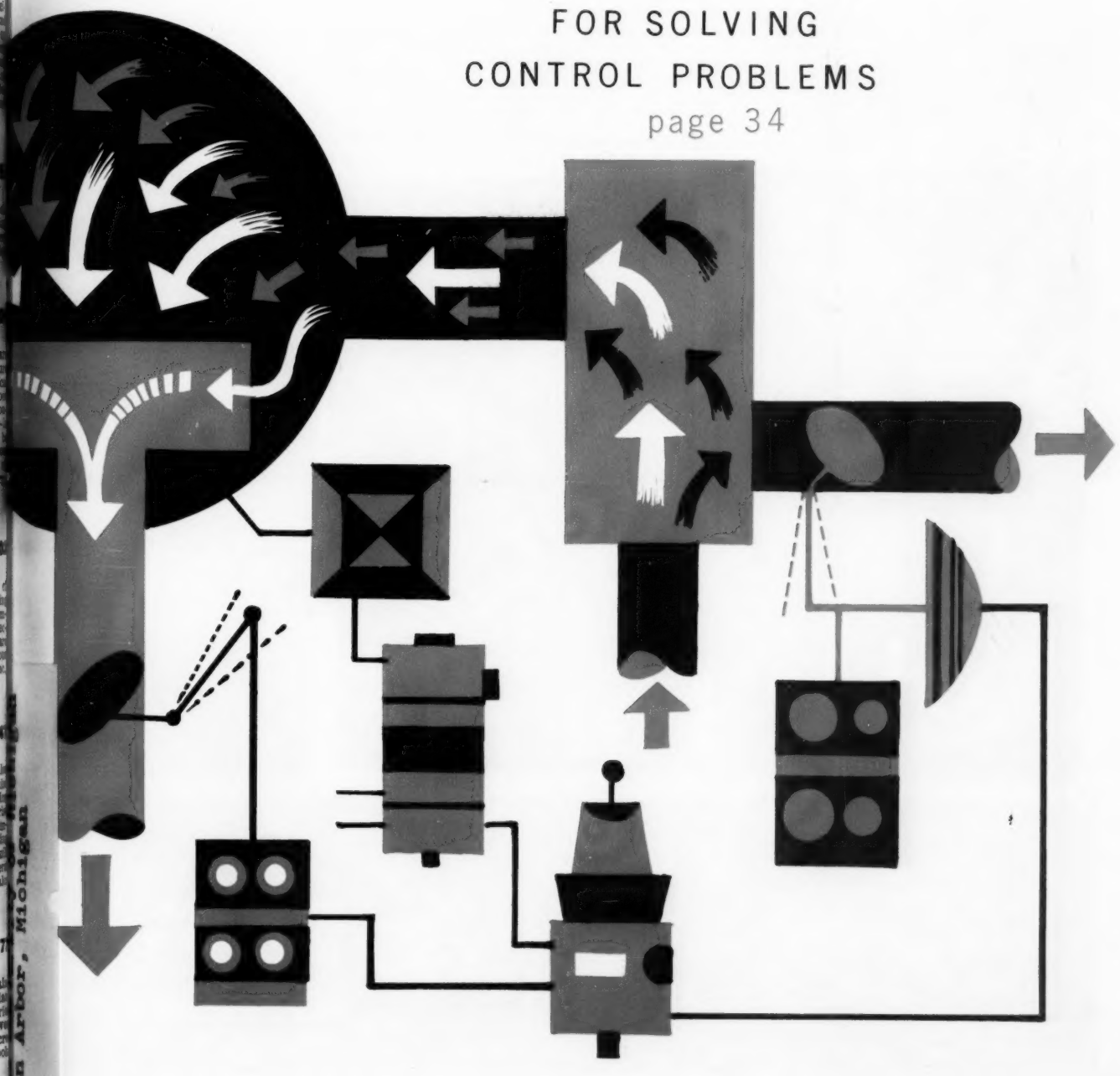
ELECTROMECHANICAL
components & systems DESIGN

APRIL 1960

7 SYSTEMS FOR SOLVING CONTROL PROBLEMS

page 34



Ann Arbor, Michigan

LIBRASCOPE SHAFT-TO-DIGITAL ENCODERS *adapt to a variety of applications, providing the direct means for presenting analog to digital data conversion with verbatim accuracy.*

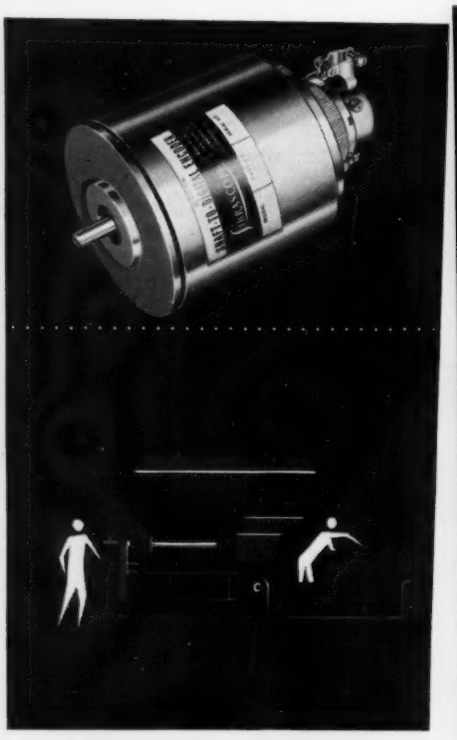
■ **RESIST ENVIRONMENTAL EXTREMES** 30g shock, 0 to 2000 cps vibration, a temperature range of −55° to +100°C. Continuous duty, noise-free operation always assured. ■ **OFFER HIGH RELIABILITY.** Multi-million shaft rotations at high speeds is typical life expectancy of these compact units. Brushes and discs of precious metals provide constant contact resistance. ■ **MEET OR EXCEED YOUR REQUIREMENTS** with 14 basic models in a wide range of capacities, *plus* custom modification and designing to your particular specifications.

■ *For full details on Librascope's shaft encoder line call our Sales Engineering department or send for Catalog E 11-1.*

accuracy that counts...

in missiles, aircraft and machine tools.

Computers... Doppler navigation... machine control... data processing equipment.



CODE OUTPUT	MODEL NO.	TOTAL CAPACITY	RESOLUTION PER TURN
SERIAL BINARY (LINEAR)	707	7 bits (128)	128
	713	13 bits (8192)	128
	717	17 bits (131,072)	128
	719	19 bits (524,288)	128
BINARY (SIN-COS)	757*	7 bits per quadrant	512
	758*	8 bits per quadrant	1024
BINARY CODED DECIMAL	723 through 735	2,000 through 360,000	200
GRAY	708	8 bits (256)	256
BINARY	740	10 bits (1024)	1024

*Available in hermetically sealed servo-driven package as Models 757-S and 758-S.

For information on career opportunities at Librascope, write Glen Seltzer, Employment Manager.

LIBRASCOPE
Division of
GENERAL PRECISION, INC.

LIBRASCOPE division **GENERAL PRECISION, INC.** • 808 WESTERN AVE., GLENDALE, CALIFORNIA

CIRCLE NO 1 ON INQUIRY CARD

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

APRIL 1960 . VOL. 4 NO. 4

Contents

Components Design

12 ELECTROMAGNETIC ACTUATORS
Important configurations of practical torque motors described in terms of fundamental electromechanical laws

24 THERMOELECTRIC MODULES
Cooling below ambient temperatures significantly reduces component failure

25 SEMICONDUCTOR DEVICE
New material in tunnel diode design permits operation above 4000 MC

26 TRAVELING WAVE AMPLIFIER
Solid state design achieves high amplification without self-oscillation

28 HYDRAULIC PRESSURE CONTROL
Motorized actuator replaces manual adjustment of valves

31 VIBRATION TESTING
Electrohydraulic systems combine high force and long strokes

32 FERRITE REED SWITCH
Microsecond memory drives metallic contacts

Systems Design

34 PROCESS CONTROL
Seven systems for solving control problems

42 HIGH SPEED PHOTOGRAPHY
100,000 magnification of time shows explosions in slow motion

New Techniques

48 X-RAY METHODS
10 basic techniques help solve problems in the application of the x-ray

Materials

50 MOLY BONDED FILMS
Lubrication for components exposed to high temperatures, corrosion, and extreme loading

Design Time Saver

56 DESIGNING FOR SPECIFIED FIELD DISTRIBUTION IN MAGNETIC CIRCUIT AIR GAPS
A simplified approach to field density problems

Components Digest

61 AUDIO AMPLIFIERS, Part III
MAGNETIC AMPLIFIERS
General considerations; equivalent circuit; saturable cores; a simple saturable reactor; parallel connected reactor circuit; feedback; self-saturation; fast response

Departments

76 ELECTROMECHANICAL COMPONENTS FOR ELECTROMECHANICAL SYSTEMS

84 ELECTRONIC COMPONENTS FOR ELECTROMECHANICAL SYSTEMS

90 INDEX TO ADVERTISERS

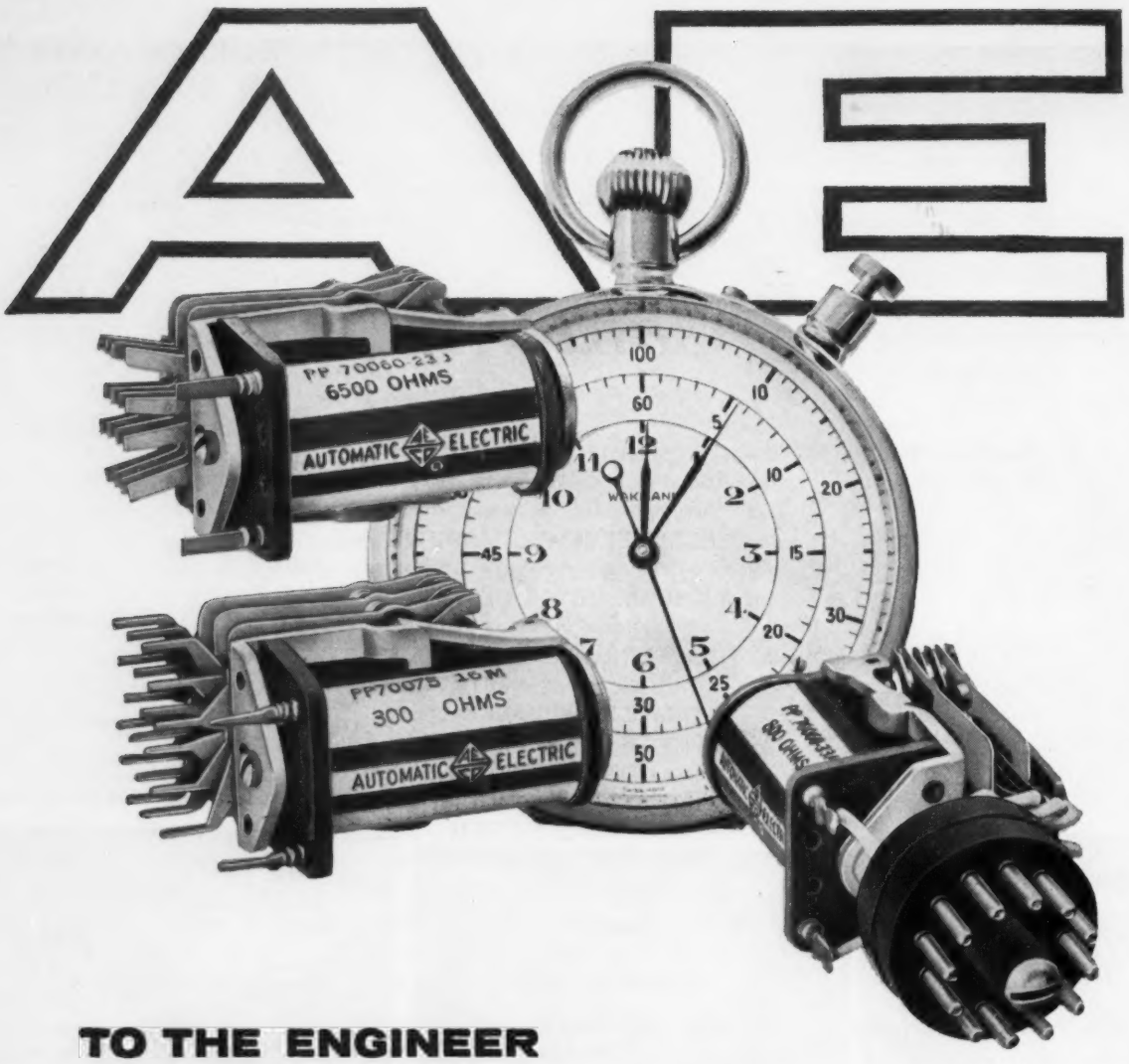
94 DATA SHEETS FOR YOUR THREE RING BINDER

BPA Circulation for April over 28,000

SUBSCRIPTION POLICY

ELECTROMECHANICAL DESIGN is circulated only to qualified research, development and design engineers in all branches of industry in the Continental United States, including government installations and universities. You can qualify for a complimentary subscription by sending the following information on your company letterhead: your name and title, your company's products; the number of engineers in your department, the number of engineers in your company and a description of your development and design functions. Please indicate whether your major engineering function is electronic, mechanical or electro-mechanical. The letter containing this information must be signed by you. Address changes for current subscribers require a re-statement of above qualifications.

Home subscriptions to qualified subscribers are available at a service fee of $2.00 per year; subscription rate for non-qualified subscribers, $10.00 for one year only; library, group or company subscriptions, $10.00 for one year only. All foreign subscriptions, $20.00 for one year. Single copy $1.00 when available.



TO THE ENGINEER

looking for a quick connection

Engineers out to cut costs at no expense of reliability can count on dramatic savings in assembly and wiring time by designing around AE Class E relays with quick-connect terminals.

Series EQPC is designed for direct insertion into printed circuits. Series EQTT, with Taper-Tab terminals, provides firm, high-conductivity connections without soldering.

AE also supplies Class E relays prewired for plug-in – with standard 8- to 20-prong octal plugs. Where additional relay protection is essential, the plug-in types are available in hermetically sealed containers or with dust-tight housings and hold-down brackets.

The AE Class E relay is a miniaturized version of the premium-quality Class B, with many of its best features. Perfect contact reliability exceeding 200 million operations is common.

AE is also equipped to supply wired and assembled, custom-built control units, *or to help you develop complete systems.*

Want details? Just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1702-E on *Relays for Industry*, and the new 32-page booklet on *Basic Circuits.*

AUTOMATIC ELECTRIC GENERAL SYSTEM

Subsidiary of

GENERAL TELEPHONE & ELECTRONICS

CIRCLE NO. 2 ON INQUIRY CARD

ELECTROMECHANICAL
components & systems DESIGN

STAFF

Publisher	H. G. Buchbinder
Editor	R. B. Brotherston
Comp. Digest Editor	Sidney A. Davis
Associate Editor	S. Henry Sacks
Associate Editor	Charlotte Kaizer
Assistant Editor	Keith Tower
Editorial Assistant	Nancy Hanrahan
Staff Columnists	David Bandel Israel Katz Emile Labin David A. Rich R. C. Vickery Martin Kagan Herbert F. Spirer Hyman Olken
Contributing Editors	H. D. Conway Oliver Haywood Joseph Hirsch George King William Seifert Martin Glasberg
Art Director	James Flora
Tech. Illustrator	J. S. Brotherston
Mgr.—Editorial Prod.	Theresa Sacks
Mgr.—Adv. Prod.	Lillian Greenberg
Dir. of Circulation	A. Allen Binder
Reader—Inquiry	Harry Kaizer Gertrude Bandel Carol Walton
Administrative Ass't.	Theodore Nichols
Ass't. to Publisher	Ruth Robinson

OFFICES

NEW ENGLAND — G. Palken
1857 Washington St.
West Newton 65, Mass.
BIgelow 4-9006

NEW YORK AREA — M. Berns, C. Lenz
11 East 63rd St.
New York 21, N.Y.
Templeton 8-4010

CHICAGO — L. Woods, D. Sturgeon, A. Boz, D. Hascall
Macintyre-Simpson & Woods
75 East Wacker Drive
Chicago 1, Illinois
Central 6-1715

CLEVELAND — L. Woods, D. Hascall
Macintyre-Simpson & Woods
1900 Euclid Avenue
Cleveland 15, Ohio
Cherry 1-1501

WEST COAST — J. Galloway, J. Harbison, D. Barton
James C. Galloway & Co.
8535 Wilshire Blvd.
Los Angeles, Calif.
OLive 3-3223

Published monthly by Benwill Publishing Corporation. Harold G. Buchbinder, President; Milton Mezer, George Palken, Robert B. Brotherston, Vice Presidents, Executive, Editorial and Subscription Office 1857 Washington St., West Newton 65, Mass. Telephone BIgelow 4-9006.
Copyright 1960 by Benwill Publishing Corporation. Accepted as controlled circulation publication at Orange, Conn.

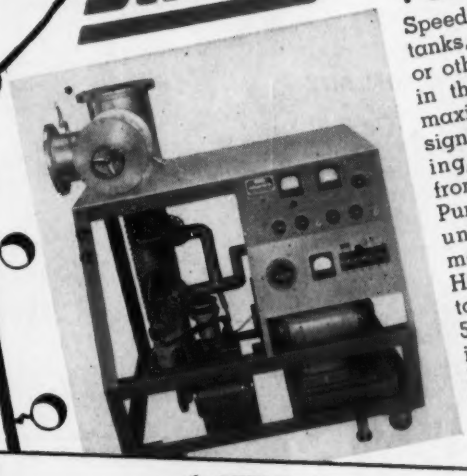
Postmaster: send form 3579 to Benwill Publishing Corporation, 1857 Washington St., West Newton 65, Mass.

PRINTED AT THE WILSON H. LEE COMPANY, 146 BOSTON POST ROAD, ORANGE, CONNECTICUT

2 IMPORTANT TOOLS FOR HIGH VACUUM PRODUCTION—

Kinney®

PW-600 HIGH VACUUM PUMPING SYSTEMS

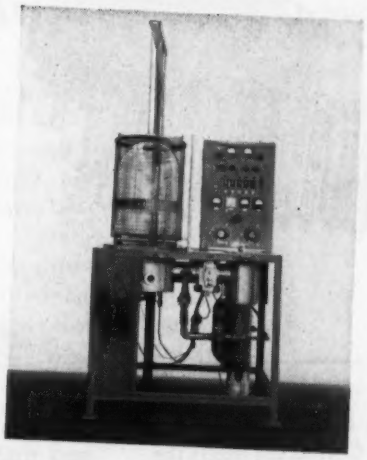


Speedy evacuation of chambers, tanks, bell jars, tubes, furnaces or other equipment to pressures in the low micron region plus maximum utility and flexibility signalize these KINNEY Pumping Systems. Readily moved from one station to another, PW Pumping Systems, because of a unique Rotatable T-Manifold, may be quickly converted to High Vacuum Evaporators. Factory tested to attain pressures to 5×10^{-6} mm Hg. without coolant in the cold trap . . . pressures below 5×10^{-7} mm Hg. with coolant in the trap.

Ask for Bulletin 4000.1

Kinney®

R-2H HIGH VACUUM EVAPORATOR



A superior unit for performing highly specialized work in optical filming and research investigations. The conventional flat base plate is replaced by a cylindrical stainless steel chamber—permitting introduction of many more and varied feed-throughs, such as: precise optical measuring equipment. This is an advanced design evaporator with extra pumping capacity and liquid nitrogen cold trap, attaining ultimate pressures of 5×10^{-8} mm Hg. It is capable of producing multi-layer films under monitored control of reflection and transmission.

Ask for Bulletin 4100.1D

WRITE FOR NEW LITERATURE ON KINNEY PUMPS AND EQUIPMENT

KINNEY VACUUM DIVISION
THE NEW YORK AIR BRAKE COMPANY

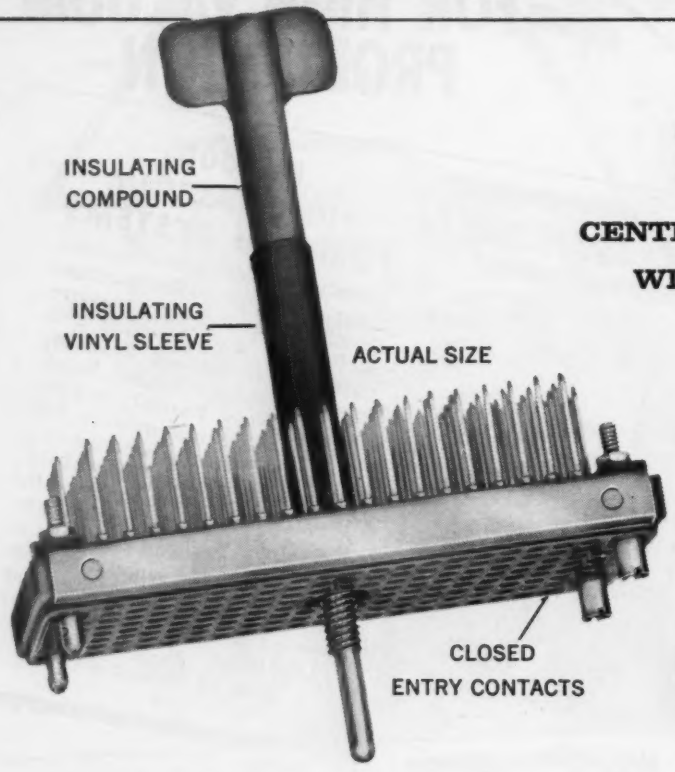
3521D WASHINGTON STREET • BOSTON 30, MASS.

Please send me ☐ Catalog on Kinney Pumps
☐ Pumping System Bulletin 4000.1
☐ Evaporator Bulletin 4100.1D

Name_____
Company_____
Address_____
City_____ Zone____ State_____

CIRCLE NO. 3 ON INQUIRY CARD

NEW!...FROM CONTINENTAL CONNECTOR



152 CONTACT

CENTER SCREWLOCK CONNECTOR WITH PROVEN RELIABILITY

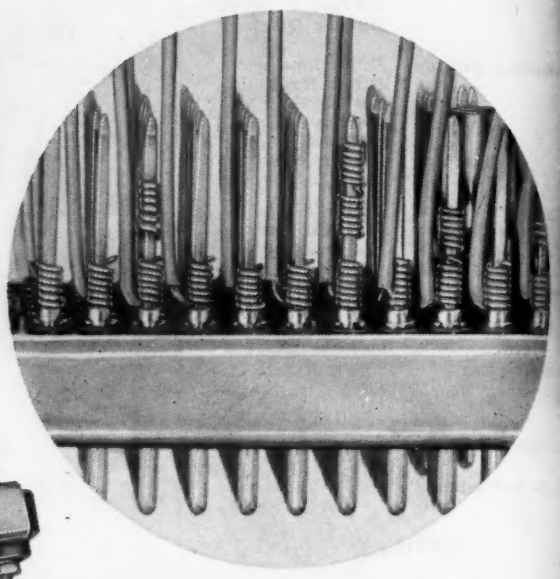
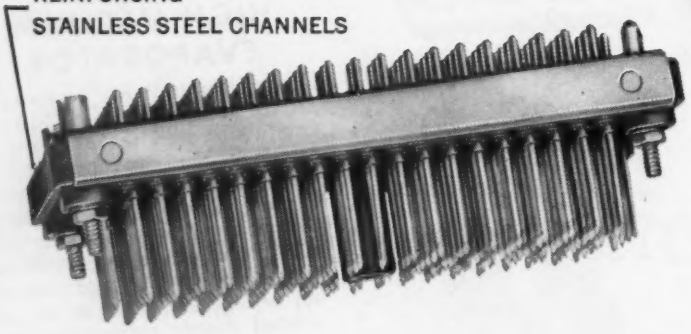
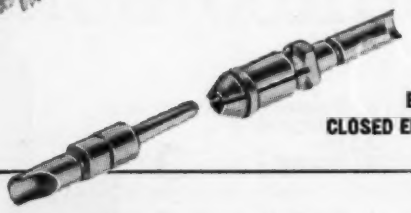


ILLUSTRATION SHOWS WIRE WRAP TERMINALS WITH ONE, TWO AND THREE WIRE CONNECTIONS





ENLARGED VIEW CLOSED ENTRY CONTACT

MINIATURE POWER CONNECTORS FOR HEAVY DUTY APPLICATIONS—Again Continental Connector meets the challenge for reliability and high precision in critical electronic equipment with these new center screwlock plug and socket connectors. They are designed for heavy duty applications requiring high dielectric and mechanical strength, partially achieved by the use of a body material molded from glass filled Diallyl Phthalate (MIL-M-19833, Type GDI-30). The double lead thread action center screwlock and stainless steel channels are extra features that contribute to the rugged construction and performance-proven reliability.

Positive polarization is assured with reversed male and female guide pins and guide sockets. In addition to the wire wrap termination illustrated, solderless taper pin or solder cup terminals can also be supplied. Note: these connectors are also available in sizes of 104, 78 or 34 contacts.

CLOSED ENTRY CONTACTS provide increased reliability and maintain a low millivolt drop under constant and uniform insertion pressure.

For complete specifications on Continental Connector's new Series 1900, write to the Electronic Sales Division, DeJUR-AMSCO CORPORATION, 45-01 NORTHERN BOULEVARD, Long Island City 1, N. Y. (Exclusive Sales Agents)

CONTINENTAL CONNECTORS

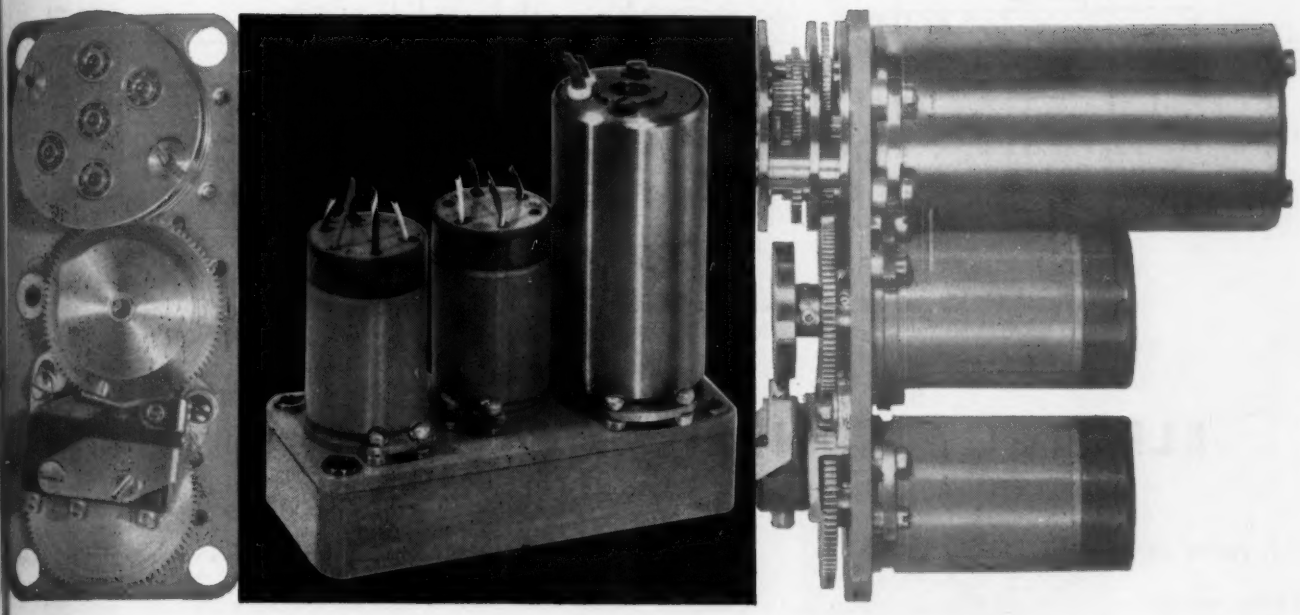
MANUFACTURED BY CONTINENTAL CONNECTOR CORPORATION, AMERICA'S FASTEST GROWING LINE OF PRECISION CONNECTO

"Wire-Wrap"—registered trademark of Gardner-Denver Co

CIRCLE NO. 4 ON INQUIRY CARD

THOMAS A. EDISON

OFFERS YOU SINGLE SOURCE RESPONSIBILITY



FOR SUB-MINIATURE ELECTRO-MECHANICAL SYSTEMS

This sub-miniature, servo-gear train system is designed and manufactured by Edison for use in airborne or ground support equipment. It is one example of Edison's unique ability to supply electro-mechanical systems in one integrated assembly.

Weighing only 9½ ounces this system contains gear train assembly, linear transformer, control transformer and motor generator. Systems such as these can be side or in-line mounted or made in any configuration to meet your requirements.

Edison has complete facilities for designing and manufacturing magnetic amplifiers, computers, transducers, miniature relays servo-motors and gear trains. Unlike other companies who must rely on outside suppliers, Edison offers you single source manufacturing and design responsibility. This is backed by one of the most complete research laboratories in the country, where experienced Edison engineers carry on a continuing program in search of new and improved state of the art designs.

Let the Edison team be your single source for servo components and electro-mechanical systems.

Thomas A. Edison Industries

INSTRUMENT DIVISION

68 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON

CIRCLE NO. 13 ON INQUIRY CARD

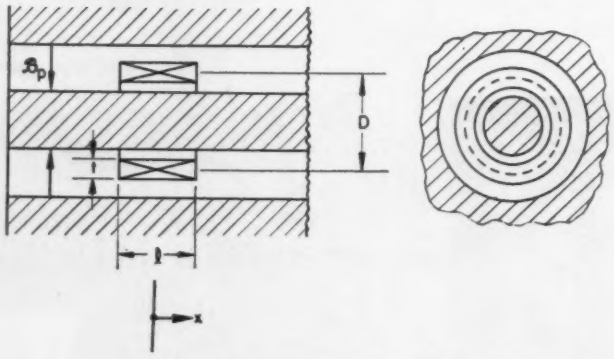


Fig. 11.1. Moving-coil device for translation.

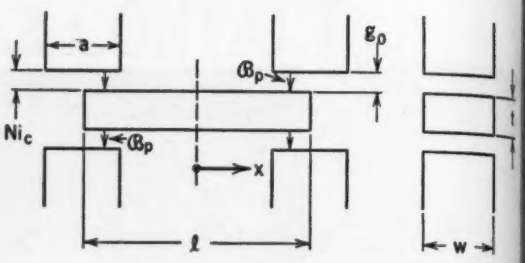


Fig. 11.3. Moving-iron device with translational motion normal to direction of airgap flux density.

ELECTROMAGNETIC ACTUATORS

PART 0

11.1. VALVE ACTUATORS

Valve actuators require for satisfactory operation and application certain minimum or maximum achievements, principally with respect to force, stroke, speed of response, sensitivity, gross bulk, linearity, hysteresis, and power consumption. The relative importance of these various quantities depends on the application. For missile applications, speed of response, sensitivity, and small size generally have priority, whereas for industrial applications, substantial force and stroke may take precedence, while response speed and bulk are not primary concerns. Whether fast action is paramount or not, a certain minimum starting force is commonly specified to give reasonable assurance that stiction and valve stroking forces can be overcome at the neutral position, in which vicinity most action takes place. Dither sometimes is provided to reduce stiction. Power consumption in itself usually is not a primary concern because the power involved generally is but a small fraction of the power involved in the controlled system. In missile applications, however, power consumption is of indirect concern owing to its influence on bulk and speed of response.

In addition to the basic requirements relating to performance and size, especially in military applications, rigid specifications concerning immunity to vibration and shock, and to environmental conditions of atmosphere and temperature, may have to be met. As in all design problems, compromises must be made since optimization with respect to one desirable feature is generally incompatible with best design from another point of view. Furthermore, theoretically optimum design conditions may be too difficult or too costly to achieve from a manufacturing standpoint, or may be insufficiently immune to environmental conditions. Therefore, while complicated over-all "figures of merit" can be developed that involve the various quantities of interest, the significance of the figure in a specific instance is questionable because in different applications different quantities require different emphases and because practical problems of manufacture and immunity to environment may overrule. Rather, the designer should have at hand a few simple criteria emphasizing certain features of design, from which he can select, as a starting guide, in accordance with his objectives. A number of such criteria are indicated for various styles of motor in Sec. 11.25.

11.2. ELECTRIC ACTUATORS

Electric actuators are of the electromagnetic type involving either moving coils or moving iron. Action is controlled either through modulation of a polarizing field by means of a control current or through modulation of an alternating reference field by modulating an alternating control current of the same frequency as the reference field. The alternating-current devices are not considered in this treatment. An a torque motor has been made and operated successfully,[1] but experience with this type of device is limited. If a suitable means of feeding an a signal to it could be developed, such a device might have considerable advantages and, even though larger than a d-c motor suited to the same job, might achieve net space saving through conservation in auxiliary electronic equipment.

Electrostatic, piezoelectric, or magnetostriction devices theoretically may be considered but practically are relatively inefficient and inadequate owing to insufficient force and stroke for reasonable sizes and driving power. Crystals are rather difficult to handle, are subject to cracking, and are rather sensitive to temperature variation. The electromagnetic types of actuators are commonly known as force motors or torque motors because their primary function is to deliver a force or torque through a small displacement in response to a control signal. Usually the action of the torque motor is converted to translational motion. An advantage of a torque motor is that it can be counterbalanced against rotation caused by high translational acceleration of the vehicle carrying it. The counterbalancing can be accomplished by splitting the valve, though difficulties may arise if slight bending of parts causes phase error of one half of the valve with respect to the other half. The torque motor can be counterbalanced against motion due to translational acceleration by use of a rocker arm, but at the expense of excess mechanism and space, and decreased speed of response.

11.21. Equations of Electromagnetic Force

Equations of electromagnetic force or torque of polarized devices can be placed in the general form

$$f = K_{1f} i_c + K_{2f} x \tag{11}$$

$$\tau = K_{1t} i_c + K_{2t} \theta \tag{11}$$

provided that operation of devices that are inherently nonlinear is restricted to an essentially linear range. Here K_{1f} and K_{1t} are called electromechanical coupling constants, i_c represents the control current, K_{2f} and K_{2t} are called electromagnetic elastance coefficients, and x and θ are, respectively, linear and angular displacements from neutral positions. The electromagnetic elastance coefficient may be positive, negative, or zero in moving-iron devices but is zero in moving-coil

[1] W. E. Sollecito, "An A-C Torque Motor—Analysis and Design." S.M. Thesis, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass., 1953.

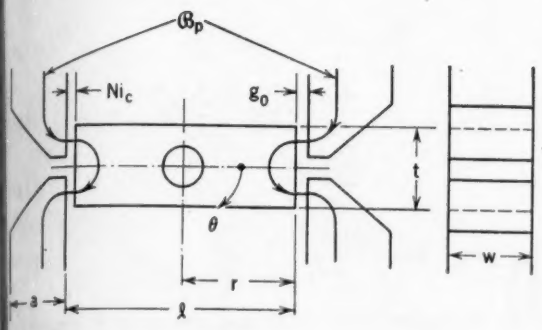


Fig. 11.4. Moving-iron device with rotational motion normal to direction of airgap flux density.

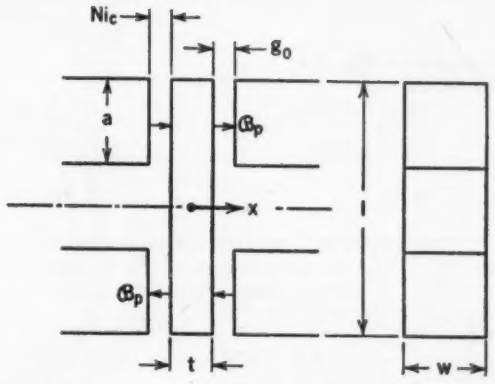


Fig. 11.5. Moving-iron device with translational motion parallel to direction of air gap flux density.

By Professor Richard H. Frazier
Associate Professor of Electrical Engineering
Massachusetts Institute of Technology

vices. As used in Eqs. 11.1 and 11.2, positive electromagnetic elastance is opposite in effect to the mechanical elastance of a centering spring, as indicated by the static equations

$$K_{0f}x = K_{1f}i_c + K_{2f}x \tag{11.3}$$

$$K_{0t}\theta = K_{1t}i_c + K_{2t}\theta \tag{11.4}$$

from which the quantities

$$K_{ef} = K_{0f} - K_{2f}$$

$$K_{et} = K_{0t} - K_{2t}$$

are defined as effective or net elastances. Obviously, for positive K_2, an unstable situation exists if K_0 is not sufficiently large. The expressions for K_1 and K_2 in terms of physical quantities involved are different for each type of device, but for any one kind of device they have the same form. Hence, derivations are made only for the moving-coil device and for two kinds of moving-iron devices (for both translatory and rotary actions) with the thought that the derivations and results for other configurations of these three kinds of devices should be similar to the illustrations. The force (or torque) equations are given in terms of the air-gap polarization flux density, $\mathcal{B}_p$, which is the air-gap flux density with the armature centered and zero control current, i_c. This polarization flux density must be established either by polarizing magnetomotive forces or by permanent magnets. The equations in terms of polarizing magnetomotive forces appear different in form from the equations in terms of polarizing fluxes or flux densities, but the one form can be translated into the other. In the limits of constant finite polarizing magnetomotive force with no associated series reluctance and constant polarizing flux with no associated shunt permeance, the equations differ in the electromagnetic elastance and nonlinear terms. Since the upper limit of pull at an air gap is determined practically by a reasonable upper limit of flux density in the adjacent magnetic material, equations that involve flux density are convenient for preliminary design exploration.

For the moving-coil device in translation, Fig. 11.1, the force equation is simply

$$f = \mathcal{B}_p \pi D N i_c \tag{11.5}$$

in which $\mathcal{B}_p$ is the radial flux density of the polarizing field in the air gap, D is the mean diameter of the coil, and N is the number of turns on the coil. Hence

$$K_{1f} = \mathcal{B}_p \pi D N \tag{11.6}$$

$$K_{2f} = 0 \tag{11.7}$$

No matter how skilled a "systems minded" engineer may be, he cannot push a system's performance to "state of the art" limits without a thorough understanding of the performance factors of the major components.

This article, taken from Chapter 11 of "Fluid Power Control", edited by John F. Blackburn, Gerhard Reethof and J. Lowen Shearer, copyrighted by Massachusetts Institute of Technology and recently published by MIT Technology Press and John Wiley and Sons, Inc., deals in considerable depth with a major component of hydraulic control systems. In this chapter, Professor Frazier describes the important configurations of practical torque motors in terms of fundamental electromechanical laws so that their ultimate limitations are apparent. These laws may also be applied directly or indirectly to an understanding of solenoids, magnetic actuators, relays and related devices. Part II of this article will be published in the May issue.

The book "Fluid Power Control" is a basic mathematical analysis of fluid power devices, with abundant design information on hydraulic and pneumatic systems and components. Copies of the book (priced at $17.50) may be ordered directly from Technology Press, Room 14 N-228, Massachusetts Institute of Technology, Cambridge, Mass. Descriptive literature detailing the book's twenty chapters may be had by circling No. 112 on the reader inquiry card.

and the device theoretically is linear if operation is restricted to the range of constant $\mathfrak{B}_p$.

For the rotational counterpart, Fig. 11.2,

$$\tau = \mathfrak{B}_p h D N i_c \tag{11.8}$$

$$K_{1t} = \mathfrak{B}_p h D N \tag{11.9}$$

$$K_{2t} = 0 \tag{11.10}$$

The moving-iron device may have its motions either normal or parallel to the direction of the air-gap flux density. For normal action, Fig. 11.3,

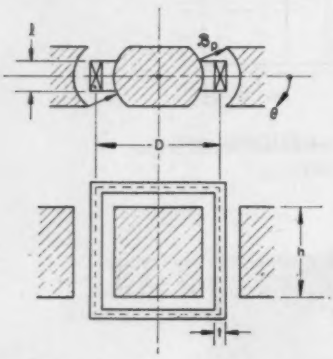


Fig. 11.2. Moving-coil device for rotation.

$$f = 4\mathfrak{B}_p w N i_c \tag{11.11}$$

$$K_{1f} = 4\mathfrak{B}_p w N \tag{11.12}$$

$$K_{2f} = 0 \tag{11.13}$$

if the motion is restricted within the central portions of the poles, and the reluctance of magnetic material in the control flux path is negligible. If the control magnetomotive force causes appreciable reluctance drop in magnetic material, K_{2t} is negative; the device then is self-centering, within a residual range determined by magnetic hysteresis, just as if it had a mechanical centering spring attached to it. This action is discussed further in Sec. 11.25 in association with interpretation of over-all electromechanical performance of the devices.

For the rotational counterpart, Fig. 11.4,

$$\tau = 4\mathfrak{B}_p w r N i_c \tag{11.14}$$

$$K_{1t} = 4\mathfrak{B}_p w r N \tag{11.15}$$

$$K_{2t} = 0 \tag{11.16}$$

For parallel action of the moving-iron device, Fig. 11.5,

$$f = \frac{4wa}{[1 - (x/g_0)^2]^2}\left(\frac{\mathfrak{B}_p N}{g_0} i_c + \frac{\mathfrak{B}_p{}^2}{\mu_a g_0} x + \frac{\mu N^2}{g_0{}^3} i^2 x + \frac{\mathfrak{B}_p N}{g_0{}^3} i x^2\right) \tag{11.17}$$

and if $x \ll g_0$ and $N i_c / 4 g_0 \ll \mathfrak{B}_p$,

$$f \approx \frac{4\mathfrak{B}_p waN}{g_0} i_c + \frac{4\mathfrak{B}_p{}^2 wa}{\mu_a g_0} x \tag{11.18}$$

$$K_{1f} = \frac{4\mathfrak{B}_p waN}{g_0} \tag{11.19}$$

$$K_{2f} = \frac{4\mathfrak{B}_p{}^2 wa}{\mu_a g_0} \tag{11.20}$$

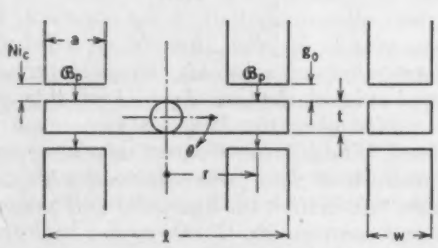


Fig. 11.6. Moving-iron device with rotational motion parallel to direction of air-gap flux density.

For the rotational counterpart, Fig. 11.6,

$$\tau = \frac{4wa}{[1 - (\theta/\theta_0)^2]^2}\left(\frac{\mathfrak{B}_p N}{\theta_0} i_c + \frac{\mathfrak{B}_p{}^2 r}{\mu_a \theta_0} \theta + \frac{\mu_a N^2}{\theta_0{}^2 r} i_c{}^2 \theta + \frac{\mathfrak{B}_p N}{\theta_0{}^3} i_c \theta^2\right) \tag{11.21}$$

in which

$$\frac{x}{r} = \theta \tag{11.2}$$

$$\frac{g_0}{r} = \theta_0 \tag{11.2}$$

or

$$\tau \approx \frac{4\mathfrak{B}_p waN}{\theta_0} i_c + \frac{4\mathfrak{B}_p{}^2 wa}{\mu_a \theta_0} \theta \tag{11.2}$$

$$K_{1t} = \frac{4\mathfrak{B}_p waN}{\theta_0} \tag{11.2}$$

$$K_{2t} = \frac{4\mathfrak{B}_p{}^2 war}{\mu_a \theta_0} \tag{11.2}$$

Sometimes mechanical construction and separation of control flux paths and polarizing flux paths are facilitated, compactness is increased or accessibility of moving parts is improved by use of a magnetic structure that contains a nonworking gap, for which the common E-I structure serves as an example. For Figs. 11.7*a* and 11.8*a*, the equations are

$$f = 2\mathfrak{B}_p w N i_c - \frac{2\mu_a w N^2}{g_0 l_0 \left(\frac{\mathfrak{R}_0}{2\mathfrak{R}_n} + 1\right)} i_c{}^2 x \tag{11.2}$$

$$\tau = 2\mathfrak{B}_p w r N i_c - \frac{2\mu_a w r^2 N^2}{g_0 l_0 \left(\frac{\mathfrak{R}_0}{2\mathfrak{R}_n} + 1\right)} i_c{}^2 \theta \tag{11.2}$$

in which

$$\mathfrak{R}_0 = \frac{g_0}{\mu_a l_0 w} \tag{11.2}$$

and $\mathfrak{R}_n$ is the reluctance of the nonworking gap. For Figs. 11.7*b* and 11.8*b*, the equations are

$$f = \frac{2\mathfrak{B}_p w}{\left(\frac{2\mathfrak{R}_n}{\mathfrak{R}_0} + 1\right)} N i_c - \frac{2\mathfrak{B}_p w g_0}{\mu_a l_0 \left(\frac{\mathfrak{R}_0}{2\mathfrak{R}_n} + 1\right)} x \tag{11.2}$$

$$\tau = \frac{2\mathfrak{B}_p w r}{\left(\frac{2\mathfrak{R}_n}{\mathfrak{R}_0} + 1\right)} N i_c - \frac{2\mathfrak{B}_p{}^2 w g_0 r^2}{\mu_a l_0 \left(\frac{\mathfrak{R}_0}{2\mathfrak{R}_n} + 1\right)} \theta \tag{11.2}$$

In terms of polarizing magnetomotive force, electromechanical coupling constants for the arrangements of Figs. 11.7*a* and 11.7*b* are the same, and those for the arrangements of Figs. 11.8*a* and 11.8*b* are the same. For Figs. 11.7*a* and 11.8*a*,

$$\mathfrak{B}_p = \frac{\mu_a N I_0}{g_0 \left(\frac{2\mathfrak{R}_n}{\mathfrak{R}_0} + 1\right)} \tag{11.2}$$

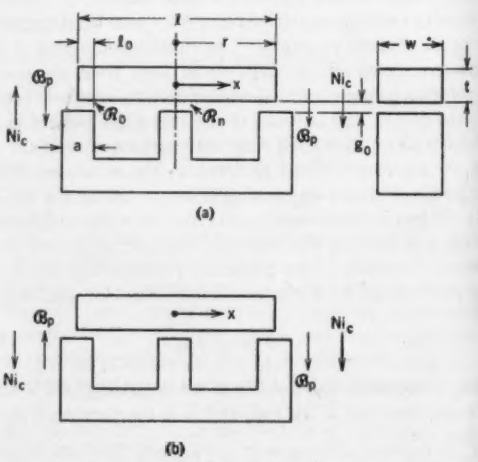


Fig. 11.7. E-I structure for translational motion normal to direction of air-gap flux density.

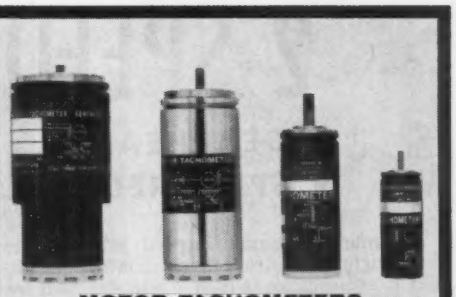
FROM AMERICAN ELECTRONICS

5

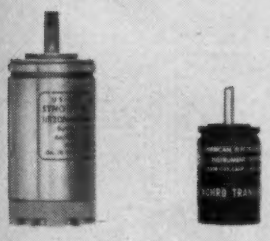
complete lines of precision servo components

You can depend on one reliable source, American Electronics Instrument Division, for servo components that meet your highest standards of **precision performance** and **maximum reliability.** Only a manufacturer that offers **complete component experience** can assure you products of unmatched quality, accuracy and dependability. Specify from five complete lines—Resolvers, Synchros, Servo Motors, Motor Tachometers, and Stepper Motors—or call on AEI capabilities to design special servo components for your unique applications. For detailed information write the Instrument Division at the address below.

RESOLVERS
Sizes 8 through 32

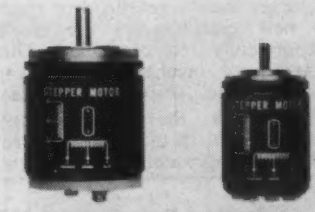


MOTOR TACHOMETERS
Sizes 8 through 18



SYNCHROS
Sizes 8 through 23

SERVO MOTORS
Sizes 8 through 18



STEPPER MOTORS
Sizes 8 through 18

AMERICAN ELECTRONICS, INC.

INSTRUMENT DIVISION

9503 WEST JEFFERSON BOULEVARD, CULVER CITY, CALIFORNIA

CIRCLE NO. 14 ON INQUIRY CARD

WASTING SPACE AND ADDING EXTRA POUNDS *IN TUNING, POSITIONING AND SCANNING SYSTEMS*

USE

BOWMAR 2-SPEED

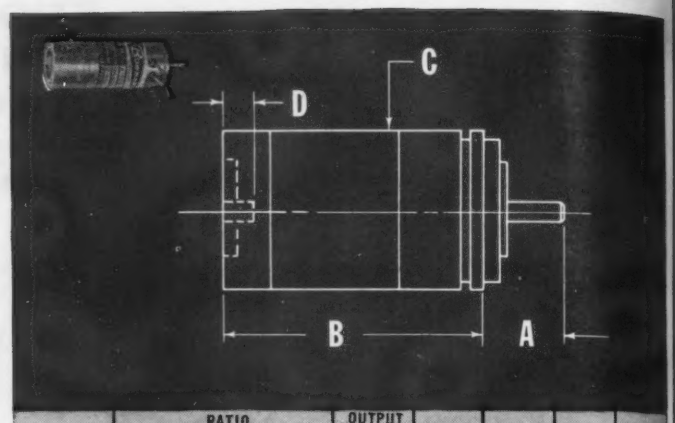
- **GEARHEADS**
- **SPEED REDUCERS**

Bowmar single-unit 2-speed gearchangers can reduce the weight and size of any control package or system which requires or which could be improved by multi-speed operation. Such systems typically include those which may benefit from fast slewing and slow zeroing. These Bowmar gearchangers permit extremely fast system dynamic response, plus slow fine-tune modes of operation which reduce inertial hunting effects.

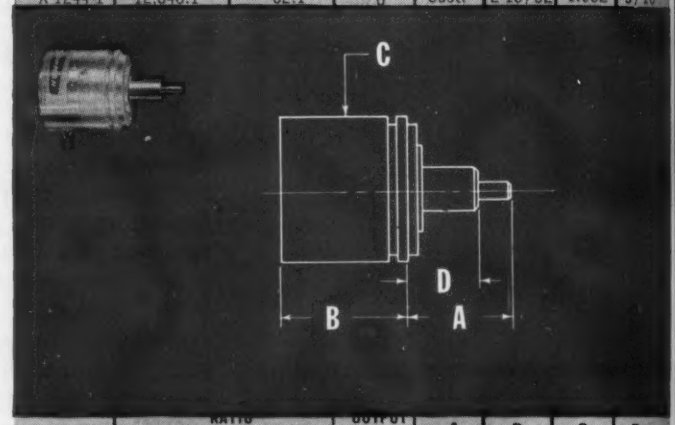
Scarely larger than a gearhead or speed reducer alone, Bowmar's new gearchangers are electrically operated and are completely self contained. They eliminate the need for outboard mechanisms, extra mounting plates and "accident prone" shifting complexes.

Bowmar produces these precision gear changers in sizes from 11 to 23, in all ratios and ratio differentials. Units shown are representative of a few Bowmar types.

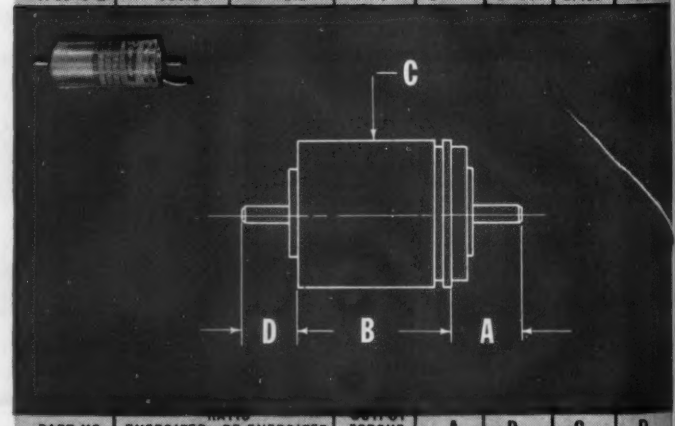
Send for Data Package 1159



PART NO.	RATIO ENERGIZED	RATIO DE-ENERGIZED	OUTPUT TORQUE (IN.-OZ.)	A	B	C	D
X- 801-1	36,600:1	20:1	6	3/8	3-11/32	1.437	9/16
X- 863-1	8:1	*1:1	3	7/16	2.000	1.062	7/16
X- 924-1	470,000:1	320:1	24	11/16	3-11/32	1.437	7/16
X- 989-3	42,978:1	26:1	5	5/8	2.450	1.062	7/16
X- 709-1	24,000:1	2,400:1	6	5/8	2.450	1.062	7/16
X- 740-1	10,000:1	100:1	6	11/16	2.376	1.437	7/16
X-1244-1	12,648:1	62:1	6	Cust.	2-19/32	1.062	9/16



PART NO.	RATIO ENERGIZED	RATIO DE-ENERGIZED	OUTPUT TORQUE (IN.-OZ.)	A	B	C	D
X- 637-1	6:1	*1:1	16	.860	1.062	1.500	.563
X- 691-3	50:1	*1:1	10	1	2.058	1.750	5/8
X- 853-1	135:1	*1:1	5	1-3/32	1.994	1.437	23/32
X- 853-2	10:1	*1:1	5	1-3/32	1.994	1.437	23/32
X-1240-1	18,500:1	50:1	4	1.132	2.750	1.437	.632
X-1240-2	5,000:1	50:1	4	1.132	2.750	1.437	.632
X-1343-1	300:1	*1:1	4	1	1.750	1.437	9/16



PART NO.	RATIO ENERGIZED	RATIO DE-ENERGIZED	OUTPUT TORQUE (IN.-OZ.)	A	B	C	D
X- 748-1	36,600:1	20:1	4	1/2	2.215	1.062	15/32
X-1008-1	36:1	*1:1	8	11/16	1-17/32	1.437	9/16
X-1008-2	1,463:1	*1:1	8	11/16	1-17/32	1.437	9/16

Running torque dependent upon input torque at least of equal value

BOWMAR INSTRUMENT CORPORATION

8000 BLUFFTON ROAD • FORT WAYNE, INDIANA

Precision Electromechanical Controls and Instrumentation, Servomechanisms
Precision Miniature Gearheads, Navigational Counters, Indicating Devices

CIRCLE NO. 15 ON INQUIRY CARD

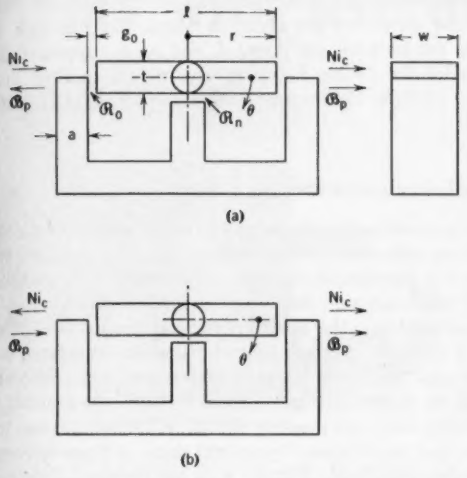


Fig. 11.8. E-I structure for rotational motion normal to direction of air-gap flux density.

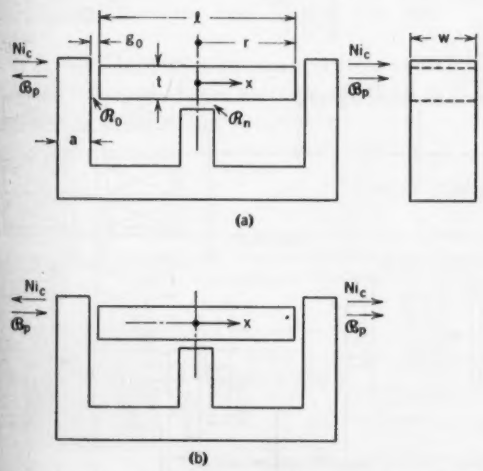
and the control magnetomotive force is Ni_c across each gap for starting, while for Figs. 11.7*b* and 11.8*b*,

$$\mathcal{R}_p = \frac{\mu_a N I_0}{g_0} \tag{11.33}$$

and the control magnetomotive force is $Ni_c/(2\mathcal{R}_n/\mathcal{R}_0 + 1)$ across each gap for starting. Hence, for either arrangement,

$$K_{1f} = \frac{2\mu_a N^2 I_0 h}{g_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} \tag{11.34}$$

$$K_{1t} = \frac{2\mu_a N^2 I_0 h}{\theta_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} \tag{11.35}$$



11.9. E-I structure for translational motion parallel to direction of air-gap density.

For Figs. 11.9*a* and 11.10*a*,

$$\frac{2wa\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)}{\left[\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1 - \left(\frac{x}{g_0}\right)^2\right]^2}\left[\frac{\mathcal{R}_p\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)Ni_c}{g_0} + \frac{\mathcal{R}_p{}^2\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)x}{\mu_a g_0} + \frac{\mu_a N^2 i_c{}^2 x}{g_0{}^3} + \frac{\mathcal{R}_p N i_c x^2}{g_0{}^3}\right] \tag{11.36}$$

which

$$\mathcal{R}_0 = \frac{g_0}{\mu_a wa} \tag{11.37}$$

or

$$f \approx \frac{2\mathcal{R}_p waN}{g_0} i_c + \frac{2\mathcal{R}_p{}^2 wa}{\mu_a g_0} x \tag{11.38}$$

$$\tau \approx \frac{2\mathcal{R}_p waN}{\theta_0} i_c + \frac{2\mathcal{R}_p{}^2 war}{\mu_a \theta_0} \theta \tag{11.39}$$

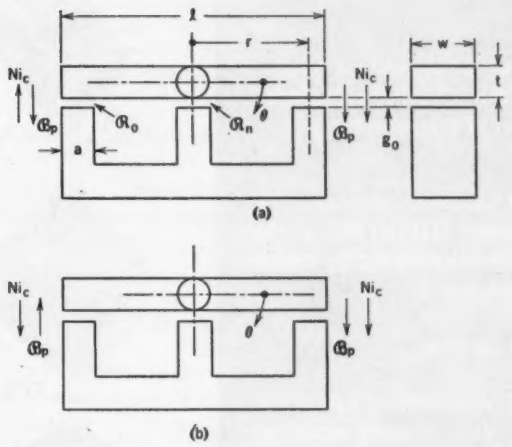


Fig. 11.10. E-I structure for rotational motion parallel to direction of air-gap flux density.

for the linear range. For Figs. 11.9*b* and 11.10*b*,

$$f = \frac{2wa}{\left[\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1 - \left(\frac{x}{g_0}\right)^2\right]^2}\left[\frac{\mathcal{R}_p\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)Ni_c}{g_0} + \frac{\mathcal{R}_p{}^2\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)x}{\mu_a g_0} + \frac{\mu_a N^2 i_c{}^2 x}{g_0{}^3} + \frac{\mathcal{R}_p N i_c x^2}{g_0{}^3}\right] \tag{11.40}$$

or

$$f \approx \frac{2\mathcal{R}_p waN}{g_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} i_c + \frac{2\mathcal{R}_p{}^2 wa}{\mu_a g_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} x \tag{11.41}$$

$$\tau \approx \frac{2\mathcal{R}_p waN}{\theta_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} i_c + \frac{2\mathcal{R}_p{}^2 war}{\mu_a \theta_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} \theta \tag{11.42}$$

for the linear range.

In terms of polarizing magnetomotive force, the electromechanical coupling constants for the arrangements of Figs. 11.9*a* and 11.9*b* are the same, and those for the arrangements of Figs. 11.10*a* and 11.10*b* are the same. For Figs. 11.9*a* and 11.10*a*,

$$\mathcal{R}_p = \frac{\mu_a N I_0}{g_0\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} \tag{11.43}$$

and the control magnetomotive force is Ni_c across each gap for starting, while for Figs. 11.9*b* and 11.10*b*,

$$\mathcal{R}_p = \frac{\mu_a N I_0}{g_0} \tag{11.44}$$

and the control magnetomotive force is $Ni_c/(2\mathcal{R}_n/\mathcal{R}_0 + 1)$ across each gap for starting. Hence, for either arrangement,

$$K_{1f} = \frac{2\mu_a N^2 I_0 wa}{g_0{}^2\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} \tag{11.45}$$

$$K_{1t} = \frac{2\mu_a N^2 I_0 wa}{r\theta_0{}^2\left(\frac{2\mathcal{R}_n}{\mathcal{R}_0} + 1\right)} \tag{11.46}$$

what is
LOW COST?

Your initial purchase price is only a fraction of the true cost of your components.

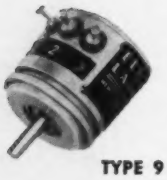
We can reduce your cost, because ELECTRO-MEC precision potentiometers and digitometers are delivered

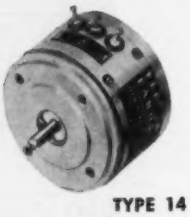
- on time
- with certified calibration data, including recordings of output function for both linear and non-linear instruments.

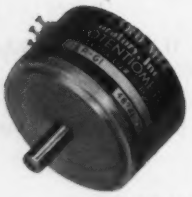
Therefore you

- save on receiving inspection cost
- enjoy assured performance after installation
- incur no production schedule delays.

You can rely on the experience and workmanship of ELECTRO-MEC


TYPE 9


TYPE 14


TYPE 18

TYPE 30

RELIABILITY
= LOW COST

Only a few of our instruments are shown here.

Write or phone our engineering department.

ELECTRO-MEC LABORATORY, INC.
47-51 33 Street, Long Island City 1, New York
STillwell 4-2407

CIRCLE NO. 16 ON INQUIRY CARD

but the electromagnetic elastances and $i_c^2 x$ terms are different. If any of these E-I structures are made as double E-I four-pole structures, the forces (or torques) are doubled, and as $\mathcal{G}_n$ approaches zero, the equations for the double E-I structures reduce to Eqs. 11.11, 11.14, 11.17, and 11.21, or the linearized versions of Eqs. 11.17 and 11.21.

11.22. Coil Arrangements

Coil arrangements for obtaining the combinations of polarizing and control fluxes indicated schematically in Figs. 11.1 to 11.10, often in association with permanent magnets, are numerous, frequently dictated by space requirements. Some arrangements, various ones of which achieve substantially the same operational results, are illustrated in Figs. 11.11 to 11.30. Though control magnetomotive force is indicated as Ni_c per gap, sometimes the same coils supply two control-flux paths in parallel, as shown in Figs. 11.26 and 11.27. In general, to reduce leakage fluxes, coils and magnets should be located as near to air gaps as feasible, but restrictions of space and shape or manufacturing simplifications often dominate. Usually coils are operated from a push-pull vacuum-tube amplifier. The quiescent currents may be used to supply the polarizing field, Fig. 11.11, but if a permanent magnet is used, the coils may be arranged so that the magnetic effects of the quiescent currents cancel. In either situation, the quiescent currents give the principal power loss in the device.* A moving-coil device must have two coils or must have a midtapped coil for push-pull operation. Such operation gives twice the maximum dissipation in coil heating, concentrated in half the winding, as does operation with control current only, to obtain

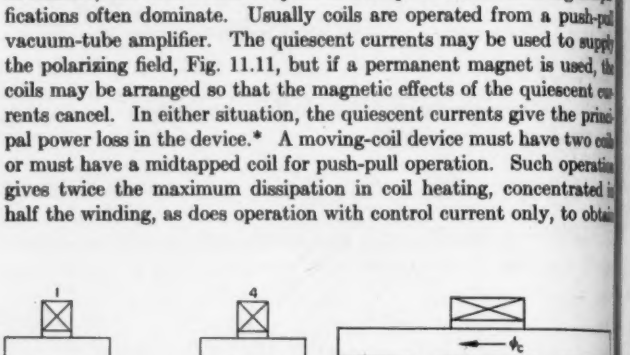


Fig. 11.12

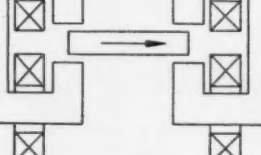


Fig. 11.11

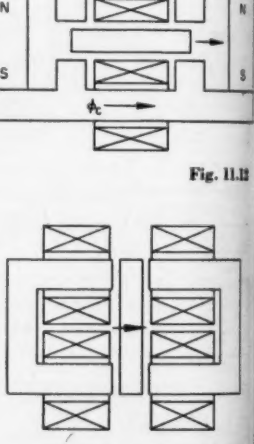


Fig. 11.13

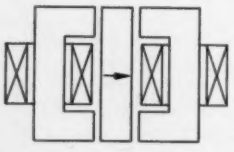


Fig. 11.14

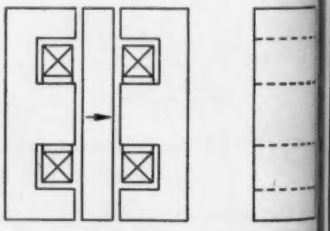
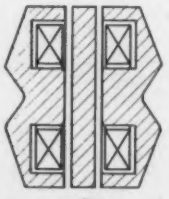


Fig. 11.15



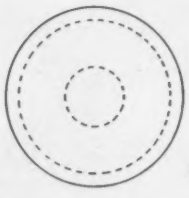
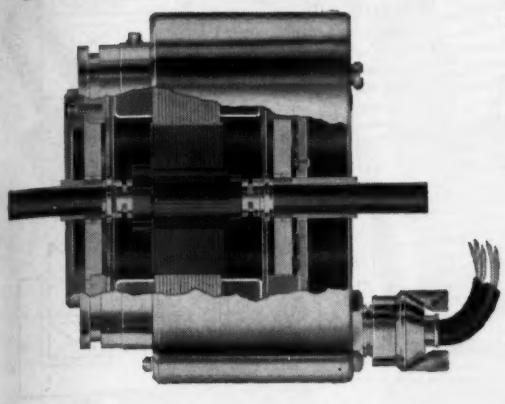


Fig. 11.16.

Figs. 11.11–11.16 Various coil and magnetic-circuit arrangements.

NOW ultra-accuracy possible in 2-speed servo systems with use of Ketay Vernier Resolvers



Ketay has developed a Vernier Resolver which permits the Systems Engineer to achieve utmost accuracy in his two-speed system. Replacing the fine speed transmitter and associated gearing on one end, and the fine speed receiver with coarse-to-fine gearing on the other end, it provides a basic system accuracy from input to output shaft of the order of 20 seconds of arc, maximum.

Operating on a variable reluctance principle, this resolver accomplishes its gear-up electrically . . . permitting coarse and fine speed units to be coupled directly. Thus, costly gearing with its contributing errors is eliminated. Also, as a variable reluctance device, it requires no windings on the rotor and therefore no sliprings or brushes. Errors due to brush contact resistance are eliminated, while greater reliability, extremely low breakaway torque and longer life are achieved.

The Vernier Resolver, in conjunction with a standard resolver, may also be used as a highly precise shaft angle encoder.

TYPICAL SPECIFICATIONS

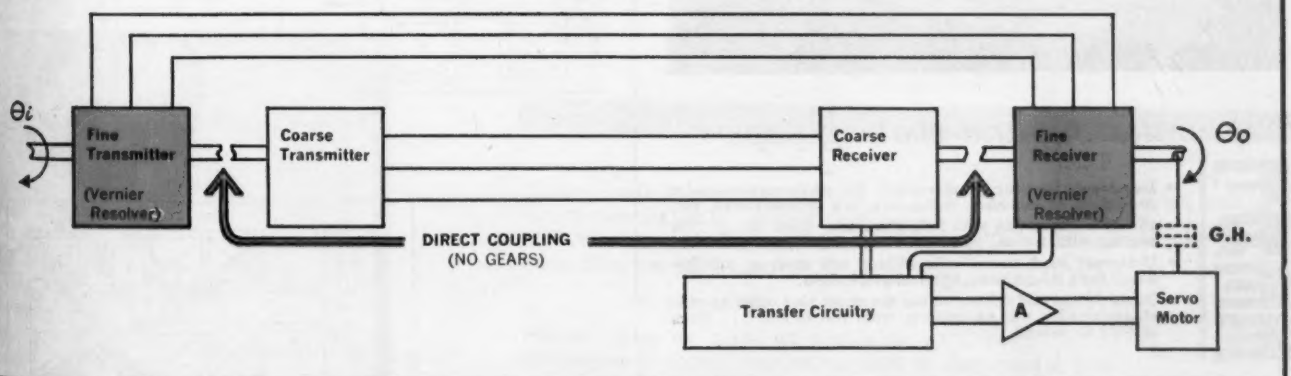
These typical specifications are for a particular vernier resolver designed for a specific application and are included here to give a general idea of what parameters are available. Vernier resolvers can be supplied for a wide range of voltages, currents and frequencies. Electrical to mechanical ratios can be changed to suit specific needs.

	Type #	SP 164
	Electrical to Mechanical Ratio (Gear up)	64 : 1
	Excitation	10 volts, 2.441 K.C.
	Error Spread of Null Crossover points (Max.)	12 (seconds)
(3), (2)	Error Spread over a Vernier interval (Max.)	4.5 (minutes)
	Maximum over-lapping error between intervals—approx.:	21 (seconds)
	Peak Output Voltage: (volts)	2.3 ± 10%
	Peak Output Voltage on reference winding: (volts)	2.5 ± 4%
	Open Circuit excitation current (untuned) (amps)	0.64 ± 4%
	Open Circuit excitation current (tuned) (amps)	0.065 ± 10%
	Open Circuit power (watts)	0.65 ± 10%
	Max. Starting Torque (in-oz.)	0.1
	Input impedance (ohms)	15.6 ± 4% /84°
	Null Voltage at Zero Points: (total rms)	7.5 mv.
	Peak Third (3) harmonic voltage (mv.)	8.5
	Phase Shift of output to input, approx.	3°
	Ambient temperature (C)	−20° to + 70°
	Weight—approximately	8 lbs. 13 oz.

NOTES:
1. Configurations, size, weight, etc. can be modified to suit specific applications.
2. Error spread can be trimmed down to value of over-lapping error or less.
3. Error is for unit being used as 2 Phase Transducer.

Submit your problems to us and a qualified Ketay engineer will show you how a vernier resolver may solve them.

USE OF VERNIER RESOLVER IN TWO SPEED SYSTEM



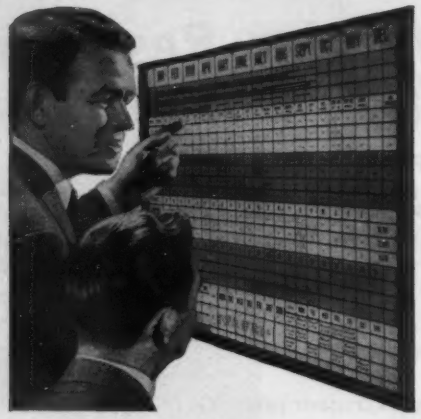
NORDEN

KETAY DEPARTMENT

NORDEN
DIVISION OF UNITED AIRCRAFT CORPORATION
Commack, Long Island, New York

CIRCLE NO. 17 ON INQUIRY CARD

GRAPHIC VISUAL CONTROL



THE BOARDMASTER SYSTEM

★ Graphic Picture of Your Operations—Spotlighted by Color
★ Facts at a Glance—Saves Time and Eliminates Confusion
★ Simple and Flexible—Easily Adapted to Your Operations
★ Easy to Operate—Type or Write on Cards, Snap on Board
★ Ideal for Production, Scheduling, Inventory, Traffic, Etc.
★ Compact, Attractive. Made of Metal. Over 500,000 in Use.

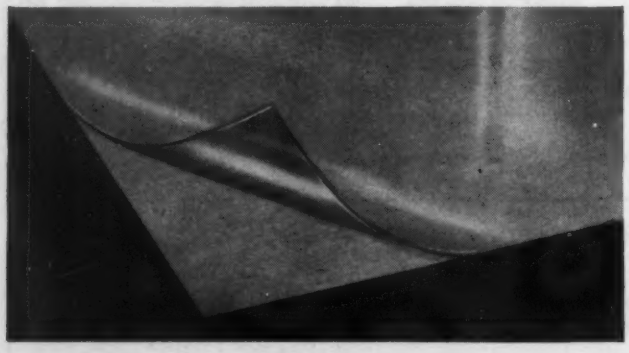
Complete Price $4950 Including Cards

FREE 24-Page ILLUSTRATED BOOKLET PR-10 Without Obligation

GRAPHIC SYSTEMS, Yancyville, North Carolina

CIRCLE NO. 18 ON INQUIRY CARD

MOSINEE MAKES MAGIC WITH PAPER



Laminating and coating papers

FREE

- Developed to your requirements for performance under conditions of moisture, mold, fire, low temperatures, etc.
- Ideal for laminating with foil, glassines, films, etc. . . . for coating with waxes, plastics, resins, organosols, plastisols.
- Uniformly hard, sound rolls without soft spots or corrugations. Free from shives, other imperfections.
- Basis weight and caliper across the sheet plus other specific characteristics will be uniform from roll to roll . . . from carload to carload.

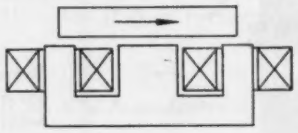
DATA FILE

Write Dept. EMD-4

MOSINEE
PAPER MILLS COMPANY
Mosinee, Wisconsin

CIRCLE NO. 19 ON INQUIRY CARD

Fig. 11.17



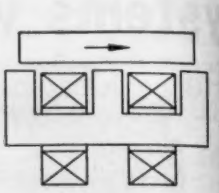


Fig. 11.18

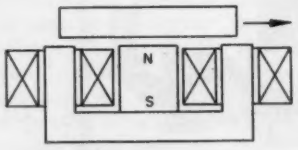


Fig. 11.19

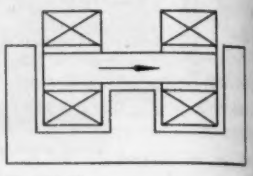


Fig. 11.20

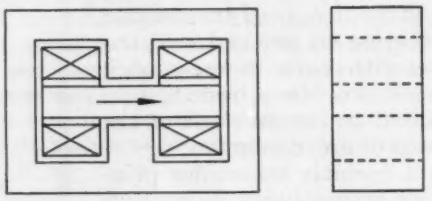


Fig. 11.21

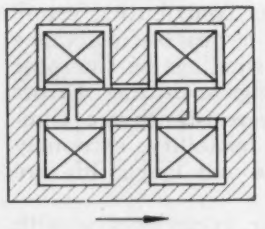


Fig. 11.22

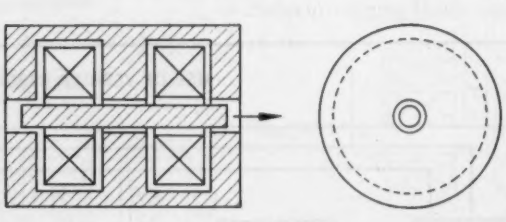


Fig. 11.23

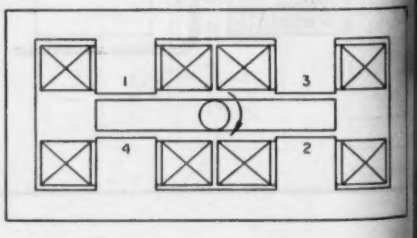
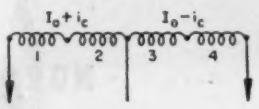
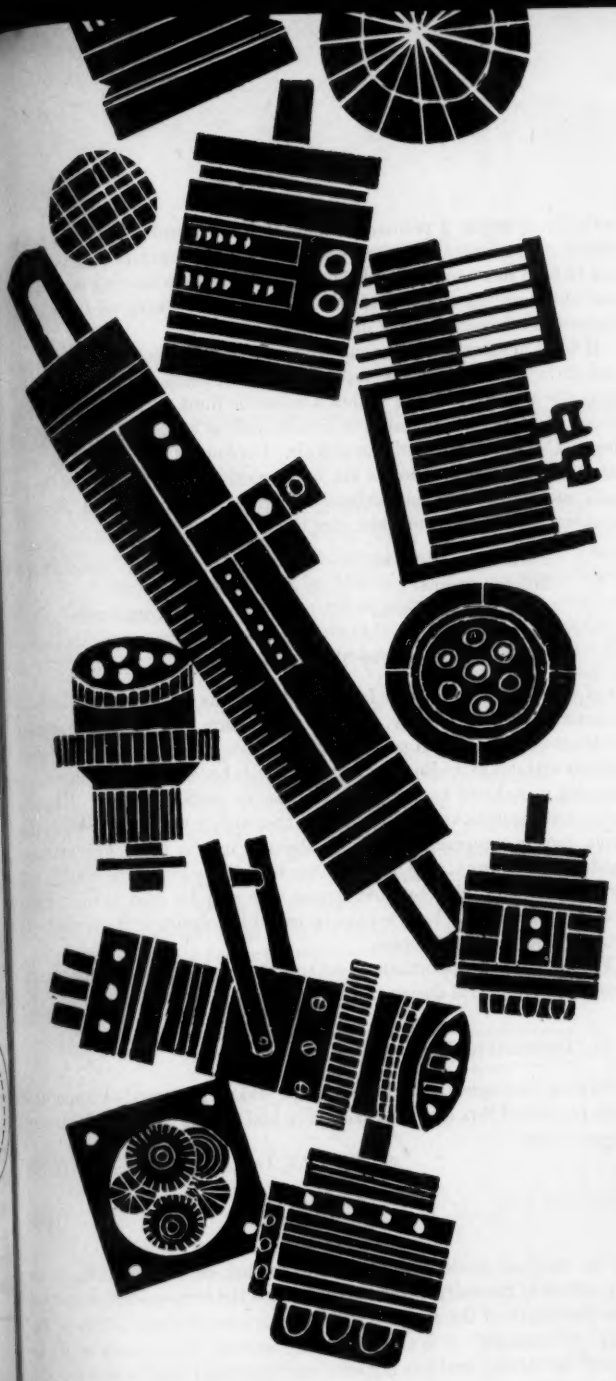


Fig. 11.24



Figs. 11.17–11.30. Various coil and magnetic-circuit arrangements.



what do you need to know about.....

- *Instrument Servomotors*
- *Precision Potentiometers*
- *Electromagnetic and Potentiometer Transducers*
- *Environmental Testing*
- *Sensitive Relays*
- *Connectors and Fasteners*
- *Analog-Digital Converters*
- *Electromechanical Switches*
- *Fractional Horsepower Induction Motors*

COMPONENTS DIGEST HANDBOOK 1

has all of the state-of-the-art answers on 200 pages of workaday information covering:

- fundamental concepts of design, selection and application
- master classification charts
- master performance charts
- master selection charts
- special specs for special applications
- design and application formulae
- standard test and procedures and definitions
- special tables and charts
- selection and design pitfalls
- failure limits and
- other design and application facts and procedures

This remarkable new kind of handbook—the first of a continuing series—brings together for the first time up-to-date selection and performance factors on important components that go into *Servomechanisms, Computers, Missiles, Aircraft Weapon Systems, Business Machines, Process Control Instruments* and other electromechanical systems.

Reserve your copy now! !

Available on or about June 25

Special pre-publication price . . . $5.00 (if check, money order or purchase order is postmarked before May 20)

Post publication price $7.00

Components Digest Editor
ELECTROMECHANICAL DESIGN
1357 Washington Street
West Newton 65, Mass.

☐ Check or money order enclosed

☐ Purchase order enclosed

Sorry, no C.O.D.s

Please ship, as soon as available . . . copy (s) of COMPONENTS DIGEST HANDBOOK ONE *at the special pre-publication price of $5.00 per copy, if paid in advance.*

NAME _____ TITLE _____

COMPANY _____

ADDRESS _____

_____ ZONE _____ STATE _____

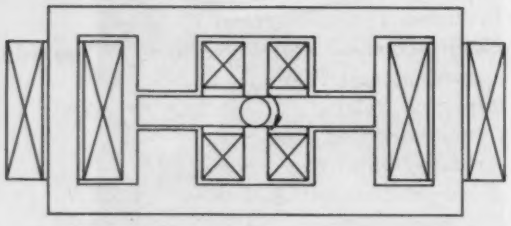


Fig. 11.25

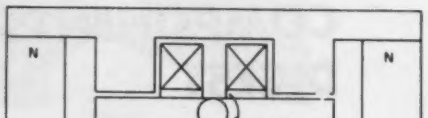
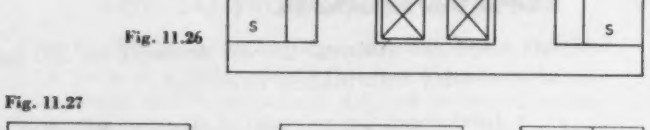


Fig. 11.26

Fig. 11.27



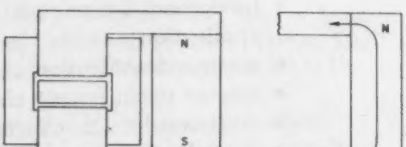


Fig. 11.28

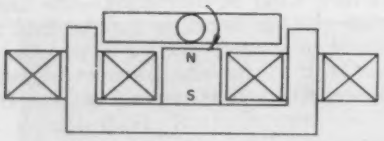


Fig. 11.29

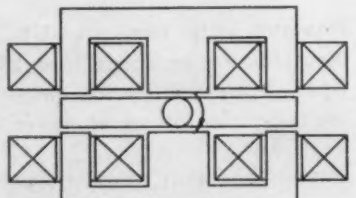


Fig. 11.30

a given force or torque, or requires a larger coil to obtain a given force or torque with a given temperature rise.

Moving-iron devices may have coil spaces that are very restricted through the necessity of making the movable part small, Figs. 11.12, 11.17 to 11.21, 11.23 to 11.30, or may have coil space limited only through the necessity of keeping the device as a whole within bounds, Figs. 11.14, 11.13, 11.15, 11.16, and 11.22. The coils may be operated push-pull and may supply both control and polarizing flux, Figs. 11.11, 11.13 to 11.18, 11.20 to 11.24, and 11.30; separate windings may be used to supply the respective fluxes, Figs. 11.11, 11.13, and 11.25; or windings may be used to supply the control flux, and permanent magnets may be used to supply the polarizing flux, Figs. 11.12, 11.19, 11.26 to 11.29. Whereas control flux and polarizing flux may be supplied by separate coils magnetically in series, a permanent magnet and control coil should not be placed magnetically in series because they have contrary functions, the one to hold flux constant and the other to provide a varying component, and the resulting control sensitivity is very low owing to the high incremental reluctance of the magnet.

If windings are kept thin enough that the difference between interior and surface temperature is not great, the size of the winding needed to keep the temperature rise within a tolerable limit may be estimated by allowing 0.005 to 0.01 watt per square inch of exposed coil surface per degree C of temperature rise in still air. Cooling, of course, can be facilitated by forced circulation of air, or by good thermal contact of the coil with metal parts having extensive surface. The nominal allowable temperatures of some magnet wire insulations are

Formex or Formvar	105°C	continuous
Silicone enamel	180°C	
Ceroc single silicone	200°C	
Teflon, Tetrox	225°C	
Ceroc single or heavy Teflon	250°C	

all of which give good space factors. Teflon has the advantage of being essentially inert chemically. These temperature limits may be exceeded for short periods, and of course current limits can be exceeded for short periods without exceeding temperature limits because of the temperature time lag introduced by the thermal capacity of the winding. Recently developed insulations, as yet not very thoroughly tried, are available for much higher temperatures than indicated in the list. For example, anodized aluminum wire may be used in the vicinity of 400°C, and ceramic-insulated nickel-plated copper wire may be used in the vicinity of 500 to 600°C. Coil space may be saved by casting coils in plastic to eliminate frames and bobbins.

The manner of apportioning control flux and polarizing flux is discussed under general design procedure, Sec. 11.26.

11.23. Permanent-Magnet Design

Permanent-magnet material and shape also are governed by apportionment of control flux and polarizing flux and by the air-gap reluctances. The relations

$$\mathcal{B}_m A_m = 2\mathcal{B}_p A \eta \tag{11.47}$$

$$\frac{\mathcal{B}_m}{\mathcal{H}_m} = \frac{l_m}{A_m}\mathcal{P}\eta \tag{11.48}$$

can be used as guides. Here $\mathcal{B}_m$ is the flux density and $\mathcal{H}_m$ is the magnetic-field intensity in the magnet, A_m is the cross-sectional area and l_m is the length of the magnet, A is a polar area (for the device of Fig. 11.27, for example), $\mathcal{P}$ is the permeance seen by the magnet in the air gaps of the device, and η is a coefficient to account for leakage flux.

The demagnetization curve of Alnico V is shown in Fig. 11.31, and Eq. 11.48 is the slope of the permeance line seen by the magnet but transposed to the $\mathcal{B}_m$-$\mathcal{H}_m$ plane so that the intersection with the demagnetization curve locates a static operating point for the magnet. If as a trial $\mathcal{B}_m$ is taken to correspond to the maximum energy product, A_m can be computed from Eq. 11.47, $\mathcal{H}_m$ can be read from the curve, and l_m then can be computed from Eq. 11.48, provided that η has been estimated. Leakage may well be of the order of 100 per cent, so $\eta = 1$ can be used as a first trial, and η can be calculated later as closely as worth while by various methods.[2] However, the static operating point is not desirable, owing to the ready possibility of inadvertent demagnetization, and A_m and l_m may not be practical for the desired structure. In general, Alnico V tends to be appropriate where A_m needs to be small and l_m can be large, whereas a material such as Alnico VII tends to be appropriate where l_m needs to be small and A_m can be large. After a trial or two for obtaining reasonable A_m and l_m, they are adjusted further in accordance with the judgment of the designer to suit the structure and to permit improved stability of operation by demagnetizing the magnet somewhat so that the operating point is on line a-b, which is an idealization of a thin minor loop.

When the magnet is of irregular shape, analysis becomes very complex owing to nonuniformity of flux density; in fact, in a magnet of uniform cross-sectional area, a similar situation exists owing to leakage flux, and

* In fact, the power dissipated in the driving amplifier and associated electronic circuits commonly far exceeds the power required by the motor. Bridge schemes can be devised that shunt the quiescent currents around the motor coils, but the net results are greater dissipation of heat elsewhere than elimination of heat from the motor and decrease in speed of response of the motor owing to reduction of impedance seen by looking out of the motor terminals.

[2] H. C. Roters, *Electromagnetic Devices*, John Wiley and Sons, New York, 1941.

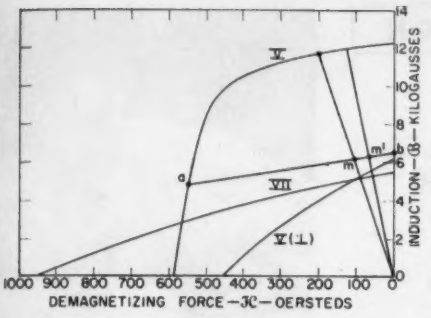


Fig. 11.31. Demagnetization curves for various Alnicos, 𝔅 versus 3C, with equivalent air-gap lines.

the magnet, therefore, sometimes is shaped to achieve more nearly uniform density by adding a "leakage shell." Furthermore, many magnets are "oriented" by cooling during the casting process in a magnetic field. The orienting should be done along lines corresponding to the desired magnetic path in the circuit of which the magnet is to be a part because magnetization at right angles to the direction of orientation is relatively difficult, as indicated by the lower curve of Fig. 11.31. For example, use of a bar magnet as in Fig. 11.27*c* requires portions of the magnetic path to go across the direction of orientation if the magnet is oriented lengthwise.

From the point of view of the device, the situation can be better appreciated by plotting the demagnetization curve in terms of flux and magnetomotive force, Fig. 11.32, derived from Fig. 11.31 by multiplying ordinates by A_m and abscissas by l_m. The operating point for the magnet is at m, but the operating point for the air gaps, armature centered, is at p, for 100 per cent leakage. If the rotor translates, Fig. 11.3, operation remains at m and p, but if the armature turns in either direction, Fig. 11.6 or 11.27, the operating points move to m' and p'. If leakage is ignored, the operating points are erroneously supposed to fall at q and q'. Likewise, for the translational device, the control magnetomotive force does not influence the polarizing flux, whereas for the rotational device,

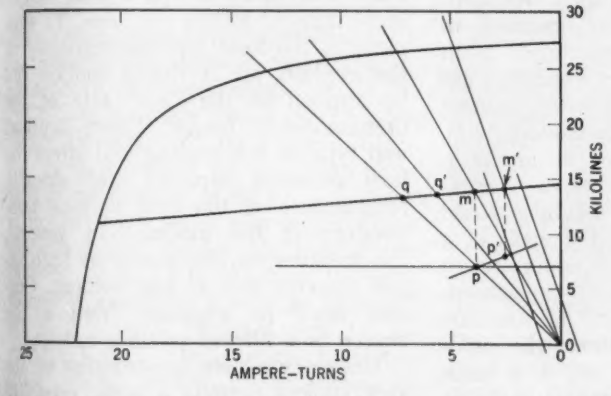


Fig. 11.32. Demagnetization curve for Alnico V, flux versus magnetomotive force, with actual air-gap lines, illustrating influence of leakage.

the displacement of the armature permits the magnet to see a fraction of the control magnetomotive force, which is represented on Fig. 11.32 by displacement of the air-gap line from the origin. This explanation illustrates the facts that leakage flux tends to emphasize the change of polarizing flux due to armature rotation and thus contributes to nonlinearity, and that a large l_m/A_m ratio tends to reduce the change of polarizing flux due to armature rotation. Increased length within limited space sometimes can be achieved by use of a horseshoe magnet.

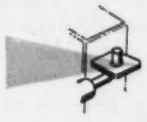
Part II of this article "Electromagnetic Actuators" will be published in the May issue.

Copies of the book "Fluid Power Control", ($17.50) from which this article is taken, may be ordered directly from Technology Press, Room 14 N-325, Massachusetts Institute of Technology, Cambridge, Mass. Descriptive literature detailing the book's twenty chapters may be had by circling No. 112 on the reader inquiry card.

UNIMAX SUBMINIATURE SWITCHES

now in 5 TERMINAL STYLES

all integral with switch contacts



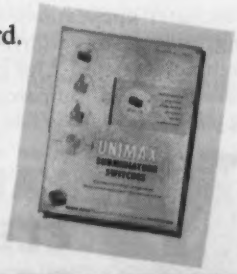
Flat, tinned lug with .058-inch hole. Just hook in end of wire, then solder.

Single-turret lug; made flat so wire won't slide around in assembly for soldering.

Double-turret flat lug — allows use of terminal as junction point.

Printed-circuit terminal; has hole for connecting component leads beneath wiring board.

Quick-Connect male terminal for snap-on wiring.



Write for catalog that gives details of UNIMAX subminiature switches.

UNIMAX SWITCH
Division, The W. L. Maxson Corporation
IVES ROAD, WALLINGFORD, CONNECTICUT

CIRCLE NO. 21 ON INQUIRY CARD

LIGHTWEIGHT

RUGGED

YARDNEY SILCAD® BATTERIES

Only ½ the size, ⅓ the weight of ordinary nickel-cadmium and lead-acid batteries . . . yet rugged enough for the most adverse conditions!

This is one reason industry is now designing with the long-life, maintenance-free YARDNEY SILCAD — economical, compact, rechargeable power for missiles, rockets, satellites and drones . . . for guidance, control, telemetering, storing energy supplied by solar energy converters . . . for such airplane and helicopter applications as engine starting, emergency lighting, power and communications . . . for portable ground power . . . and numerous commercial applications.

YARDNEY ELECTRIC CORP.

"Pioneers in Compact Power"®

40-50 LEONARD STREET, NEW YORK 13, NEW YORK

Patents granted and pending.
© 1960 by Yardney Electric Corp.

CIRCLE NO. 22 ON INQUIRY CARD

THERMOELECTRIC MODULES FOR COMPONENT COOLING

New Units Cool Components Below Ambient Temperatures

Cooling of electronic equipment by present techniques is complicated by the nonuniform distribution of heat generated by certain components. The resulting "hot-spots" cause a severe heat rise in the component, and effectively derate the total equipment and limit its maximum operating temperature. Present heat dissipating devices using ambient air techniques can only limit the temperature rise of the components above ambient temperatures but cannot cool the component below ambient temperatures.

D. W. Gunther, manager of Westinghouse Electric's Semiconductor Department at Youngwood, Pa., announces that the company is manufacturing a series of thermoelectric modules that provide a lower local temperature environment for electronic components. As a result, the probability of early component failure due to "hot spots" can be significantly reduced, and equipment can be operated in higher ambient temperatures with greater reliability. The modules are rugged, provide a controlled cooling rate, and operate with no moving parts, so they can be mounted in any position. For example, by proper orientation, a number of the modules could be constructed to form the walls of a "box", providing a compact space cooler for electronic apparatus. Through use of a variety of specially designed mounting fixtures, the modules can accommodate one or a number of electronic devices such as transistors or diodes.

Heat pumping capacity, or rate at which heat can be removed from the cold surface of the module coolers, depends on the temperature difference between the hot and cold surfaces of the cooler and on the power input to the unit. As an example, a Type WX810 module can maintain a temperature differential of 25°C with a heat load of more than 17 BTU's per hour. To supplement the heat rejection capacity of the module, air or liquid cooling can be applied to the "hot" side of the thermoelectric cooler. Exact amount and type of this cooling will affect the heat pumping capacity and ultimate temperature of the cold surface temperature of the module. In general, the modules require power at high input currents and at low voltage. Current must be supplied from a d-c source or a filtered rectifier output.

Unique modular construction of the spot coolers permits a wide range of flexibility in application. In many cases, the electronic equipment need not be redesigned to accommodate the thermoelectric devices.

Fig. 1 Electrical leads to a varied assortment of the units are being attached here. These thermoelectric cooling devices are among the first to be produced in commercial quantities according to Westinghouse Electric Corp.'s semiconductor department.

Circle No. 116 on Inquiry Card

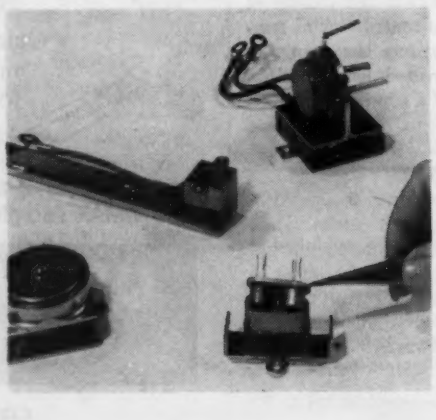


Fig. 2 Modules can be adapted with different mounting fixtures for cooling various sizes and types of transistors. By removing the cover of the unit in the right foreground, a mounting configuration for chamber-cooling two transistors can be seen. Clockwise, the illustration then shows: basic module adapted for cooling four transistors; chamber-type fitting for cooling one transistor; basic 1½-inch module adapted with a fitting for mounting a high power transistor. Basic units can be physically paralleled to cool a large flat area, or stacked in series like building blocks for increased cooling.

SEMICONDUCTOR DEVICE

Tunnel Diode Operates Above 4000 mc

Key to the improved performance of a newly developed tunnel diode is the use of gallium arsenide, a little known and rarely used semiconductor material, as the basic element. General Electric scientists stated that based on their present observations gallium arsenide is the best material for tunnel diodes so far explored and may be the ultimate material for the best overall performance. Oscillation frequencies of 4400-megacycles have been obtained indicating that frequencies well above 10,000-megacycles are possible with tunnel diodes made of gallium arsenide.

Like the transistor, the tunnel diode is a basic device in an electronic circuit but it achieves high frequency easier than the transistor and is relatively insensitive to temperature changes and nuclear irradiation. Tunnel diodes are expected to be used extensively in high speed computers, communications equipment and nuclear controls as a companion to the transistor.

Gallium arsenide tunnel diodes now under development by General Electric have exhibited peak-to-valley current ratios as high as 60 to 1. Highest ratio previously noted was in some germanium tunnel diodes which exhibit a ratio of 14 to 1. In addition, the new tunnel diodes have a voltage swing of up to 1.2 volts. According to G. E. engineers, the voltage swing characteristics can be used to fire transistors in ultra high speed computers. By comparison, germanium tunnel diodes have a voltage swing of up to 0.45 volts while silicon tunnel diodes have a peak of 0.75 volt swing.

Another important feature of the new development is the extremely high current densities obtained. According to the G. E. scientists working on the devices, gallium arsenide tunnel diodes have current densities of 5,000 to 10,000 amps per sq. cm. By comparison, the current density of commonly used 12 gauge house wire is 7,000 amps per sq. cm.

General Electric currently plans to make samples of the gallium arsenide tunnel diodes available around April, 1960.

Circle No. 123 on Inquiry Card.

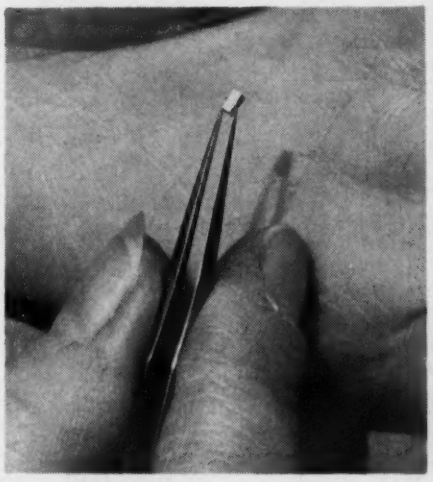


Fig. 1 General Electric's newly developed gallium arsenide tunnel diode works at frequencies above 4000 megacycles.

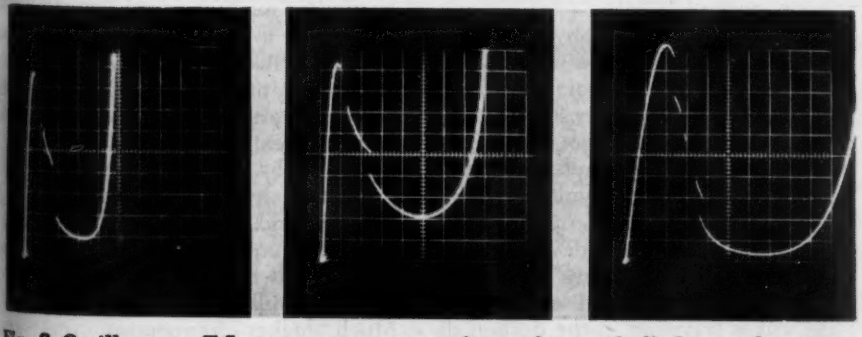


Fig. 2 Oscilloscope E-I curve trace comparison of tunnel diodes made of germanium, si icon, and gallium arsenide. General Electric has been sampling industry with germanium tunnel diodes and now plans to offer samples of its new gallium arsenide tunnel diodes.

THIS IS THE CORRECT EASY WAY

Don't chain your engineers to time-consuming routine on repetitive blueprint items . . . free them for more creative work and save countless hours of expensive drafting time with STANPAT.

STANPAT prints these items on tri-acetate sheets that are easily transferred to your tracings. No special equipment required . . . reproductions come out sharp and clear . . . and STANPAT is incredibly inexpensive.

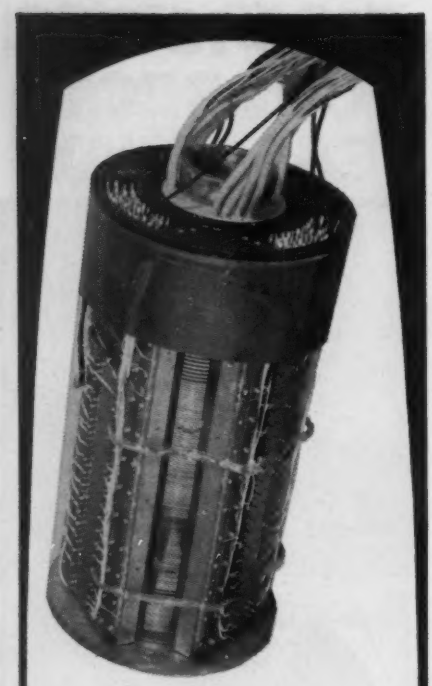
19 YEARS OF SERVICE TO INDUSTRY

STANPAT COMPANY
Whitestone 57, N. Y., U. S. A.
Phone: FLushing 9-1693-1611

☐ Please quote on enclosed samples.
☐ Kindly send me STANPAT literature and samples. Dept. 173

Name_____
Title_____
Company_____
Address_____

CIRCLE NO. 23 ON INQUIRY CARD



NEW SERIES of Antenna SLIP RING Assemblies

12 to 500 RINGS

A standardized line of large Slip Ring assemblies, designed for a multiplicity of instrumentation, control and power circuit applications. First production assemblies are in use on radio telescopes, radar and tracking antennas and human centrifuge installations.

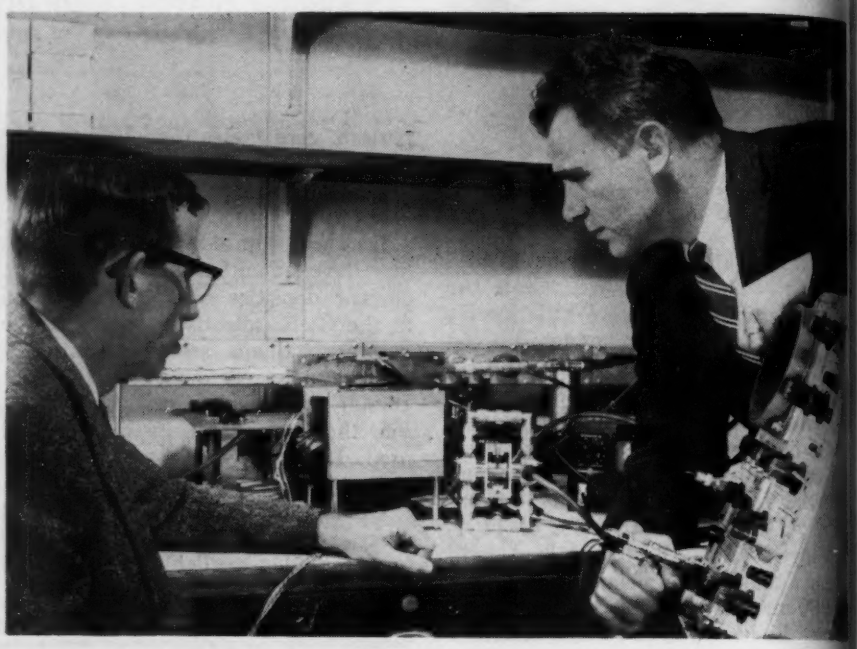
Assemblies vary from 12" to 72" in length, are either shaft or flange ball-bearing mounted and may be specified with hermetically sealed housings. Noise levels are held to a minimum. So are intercircuit losses, cross-talk and radiation, through proper shielding.

For complete information, write:

SLIP RING COMPANY of AMERICA

3612 West Jefferson Blvd., Los Angeles 16, Calif.

CIRCLE NO. 24 ON INQUIRY CARD



William W. Anderson (left) and Marion E. Hines, both of Bell Telephone Labo-atories, inspect a laboratory model of a new traveling wave solid-state amplifi-

TRAVELING WAVE AMPLIFIER

Row of Tunnel Diodes In Strip-Line Waveguide Amplifies Signal Wave

Using the negative resistance of the Esaki (tunnel) diode in combination with non-reciprocal ferrite attenuation, Bell Telephone Laboratories has developed a solid state broad-band microwave amplifier that achieves high amplification without self-oscillation. The new amplifier can be used to increase the strength of radio signals over a broad range of frequencies in the microwave range above 1000 megacycles and is expected to have applications in radar, microwave radio relay, satellite communications, and waveguide transmission systems.

The device is built on a traveling wave concept with a row of Esaki diodes along the center of a strip-line wave-guide. Negative resistance of the diodes causes the power in a signal wave to increase progressively as it travels along the waveguide. By including non-reciprocal ferrite attenuation in the structure, the device is made to absorb waves traveling in the undesired reverse direction and to amplify waves traveling in the desired direction. This feature allows a large total amplification to be obtained with complete stability by eliminating internal "feedback" which had caused oscillations and other difficulties.

The active diode used in this a- plifier was the discovery of Dr. L- Esaki of the Sony Corporation in Jap- It has aroused considerable interest the electronics industry because it i- simple semiconductor device whi- can convert direct current into use- alternating current signals in comm- nications and computer circuits. It h- only two terminals and is easier to co- struct than triode transistors or vacu- tubes, yet can do many of the s- jobs. The Esaki diode is useful b- cause it is a negative-resistance d- ment in which the current decrea- as the voltage is increased. This ca- it to add to the power of signal wa- instead of absorbing the power a- positive resistance does. Althou- negative-resistance devices have be- known for many years, the Esaki dio- is superior to previous types in its si- plicity, in its low power requirement- in the magnitude of its negative-resi- ance effect, and in its capability of o- eration at extremely high frequencies.

Bell Labs engineers state that t- present model operates most efficient- at 1000 mc. They expect, howeve- that the frequency of operation of f- ture models can be extended to abo- 3000 mc, still using germanium diod- Much higher frequencies, they s- perhaps into the millimeter wa- length range, should be possible wi- diodes of indium antimonide, whi- have been made by R. L. Batdorf, a- of Bell Laboratories.

Just off the Press!

Specifications on all standard seals—

E-I Short Form Catalogs

Bulletin SCT-59 on Single Lead Terminals

Bulletin TCT-59 on Tubular Terminals

—ask for your copies, today!

getting down to total reliability!

E-I

GLASS-TO-METAL SEALS

—in commercial equipment and vital military programs

For proven reliability in severe environments, select your seals from the E-I standard line of application tested hermetic terminals. E-I offers designers the complete flexibility and economy of standardized production on all types of seals . . . from single lead terminals to sub-miniature closures. Proof of their reliability is the fact that leading manufacturers specify E-I for every type of seal application. Request catalog on standard types, or send drawings on seals for special requirements.

ELECTRICAL INDUSTRIES

A Division of Philips Electronics & Pharmaceutical Industries Corp.

MURRAY HILL, N.J.

Patented in Canada, No. 523,390; in United Kingdom, No. 734,583; licensed in U. S. under No. 2561520

SINGLE LEAD TERMINALS | PLUG-IN CONNECTORS | CUSTOM SEALING | TRANSISTOR CLOSURES | THREADED SEALS | END SEALS | MINIATURE CLOSURES | MULTIPLE HEADERS

CIRCLE NO. 25 ON INQUIRY CARD

HIGH SPEED,
Sensitive
Polarized
RELAYS

"DIAMOND H"

SERIES P
Relays

For electronic and communications applications

Engineered to provide extremely fast action with high sensitivity, freedom from bounce and excellent stability, "Diamond H" Series P Polarized Relays give consistent performance with low distortion. Under some conditions they will handle over 1,000 pulses per second.

Magnetically latched SPDT, with two independent coils, Series P Relays are available with various coil resistances from 10 to 4,000 ohms each coil. Contact ratings will vary with switching speeds desired, but range from 60 milliamperes to 2 amperes. Extremely compact, to save space and weight, they fit standard octal sockets. Their impact and vibration resistance is excellent for relays of this type, thanks to extra-rugged construction.

"Diamond H" engineers are prepared to work out a variation to meet your specific requirements. Write or phone us your needs.

THE HART
MANUFACTURING COMPANY
272 Bartholomew Avenue
Hartford, Conn.
CIRCLE NO. 26 ON INQUIRY CARD

COMPONENTS DESIGN

Missile Battery

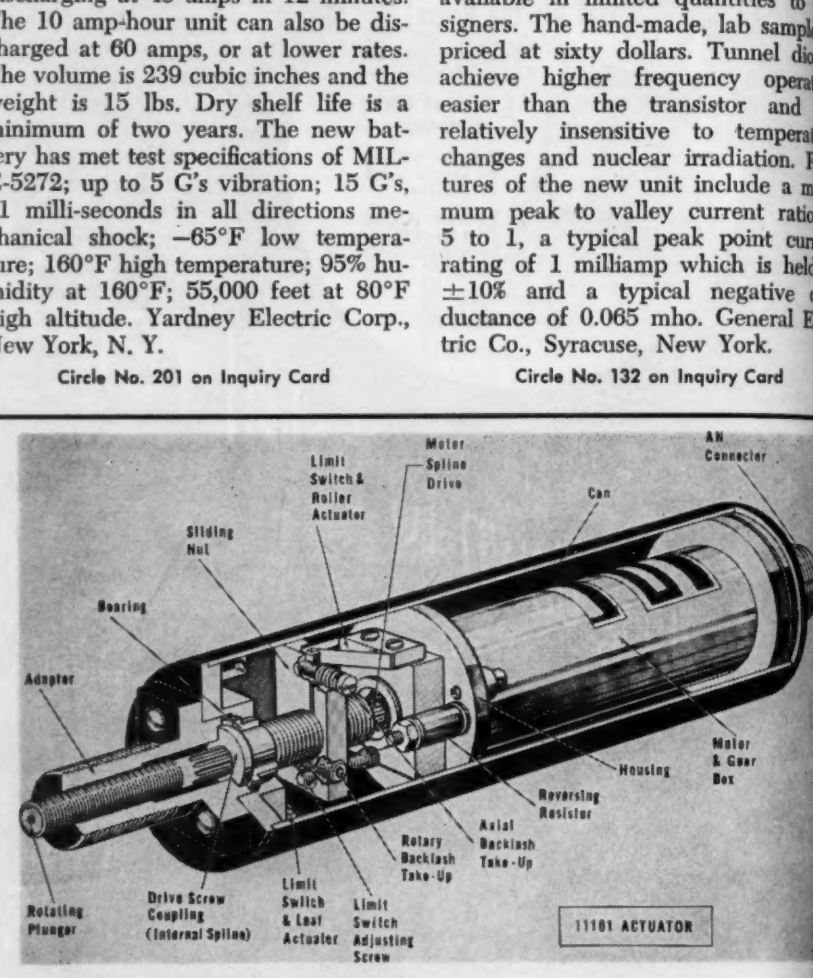
A rechargeable silver-zinc power pack has a nominal voltage of 28 volts when discharging at 45 amps in 12 minutes. The 10 amp-hour unit can also be discharged at 60 amps, or at lower rates. The volume is 239 cubic inches and the weight is 15 lbs. Dry shelf life is a minimum of two years. The new battery has met test specifications of MIL-E-5272; up to 5 G's vibration; 15 G's, 11 milli-seconds in all directions mechanical shock; –65°F low temperature; 160°F high temperature; 95% humidity at 160°F; 55,000 feet at 80°F high altitude. Yardney Electric Corp., New York, N. Y.

Circle No. 201 on Inquiry Card

New Tunnel Diode

Sample quantities of a second tunnel diode, a 1000 megacycle device is available in limited quantities to designers. The hand-made, lab sample is priced at sixty dollars. Tunnel diodes achieve higher frequency operation easier than the transistor and are relatively insensitive to temperature changes and nuclear irradiation. Features of the new unit include a minimum peak to valley current ratio of 5 to 1, a typical peak point current rating of 1 milliamp which is held to ±10% and a typical negative conductance of 0.065 mho. General Electric Co., Syracuse, New York.

Circle No. 132 on Inquiry Card



HYDRAULIC PRESSURE CONTROL

Motorized Actuator Replaces Manual Adjustment of Valves

For increased performance and reliability, a relief valve actuator has been completely redesigned to include: spline drive from motor through to rotating plunger; open "C" frame limit switch housing; anti-backlash provisions on sliding nut; and improved wire routing.

The miniature motor, with integral gear reduction, drives a rotating and axially moving shaft. The shaft accomplishes the motion of the knurled manual shaft which it replaces. The adjustable limit switches are normally set for complete open and closed positions. However, the limit switches may be set for two preselected pressures; thus two pressures can be automatically controlled. The small 28v, d-c motor can be operated easily from small control boxes. One type of control box includes a 5 position switch offering two speed operation of the actuator for both, increasing or decreasing pressure. Thus a desired setting of pressure can be rapidly approached and then slowly set to exact requirements.

Actuator permits fine, remote control of relief valves, back pressure valves (or other valves of the same basic type), and variable volume pumps and motors which require similar adjustment. Automatic programmed control can be added by using a matching servo circuit. United Hydraulics, Inc., Dayton, Ohio.

Circle No. 119 on Inquiry Card

NEW VARIABLE RESISTANCE DEVICE

Sensitive Transducer Controls Large Amount of Power

Until now, changing of physical movement into large values of electrical energy could be accomplished only by sizable units or with expensive amplification. The Regohm Transducer, developed by the Electric Regulator Corp., directly controls up to a quarter-kilowatt of power by its ability to respond to less than .0001 inch of mechanical displacement, bringing a new order of sensitivity to variable resistance devices. Any quantity which appears as a change in position can move the unit's actuator to initiate control, for example: a cam; slight bending of a heat-sensing bimetal; fluid pressure on bellows; tension developed by the winding of paper, tape or film onto reels; or a vane deflected by liquid or gas flow. Input motion causes a smooth, stepless change of resistance in the output circuit. Resistors are mounted on a chassis external to the transducer. An endless variety of resistance tapers can be selected to match specific requirements. Mechanical connection to suit a controlled machine is easily accomplished by shaping the linkage rod.

Unit's life expectancy is conservatively placed at 50,000 hours with no need for cleaning, lubrication or adjustment. No mechanical wear has been detected in units subjected to over 15 million operating cycles. Electric Regulator Corp., Norwalk, Conn.

Circle No. 122 on Inquiry Card.

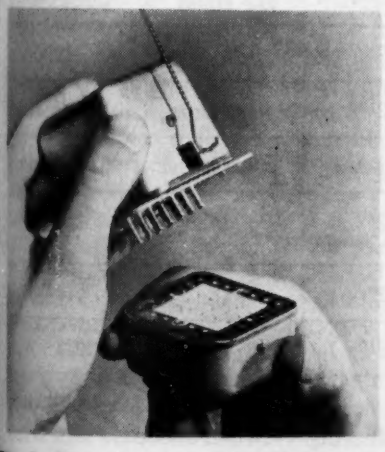


Fig. 1. Transducer developed by Electric Regulator Corp., conveniently plugs into socket which is mounted on device to be controlled. Linkage rod (near top of figure) couples to machine and responds to mechanical movement. Change in the rod's position, as small as .0001 inch, enables the Regohm transducer to control up to a quarter-kilowatt of power. Unit regulates such quantities as motor speed, fluid pressure, tension or flow of materials.

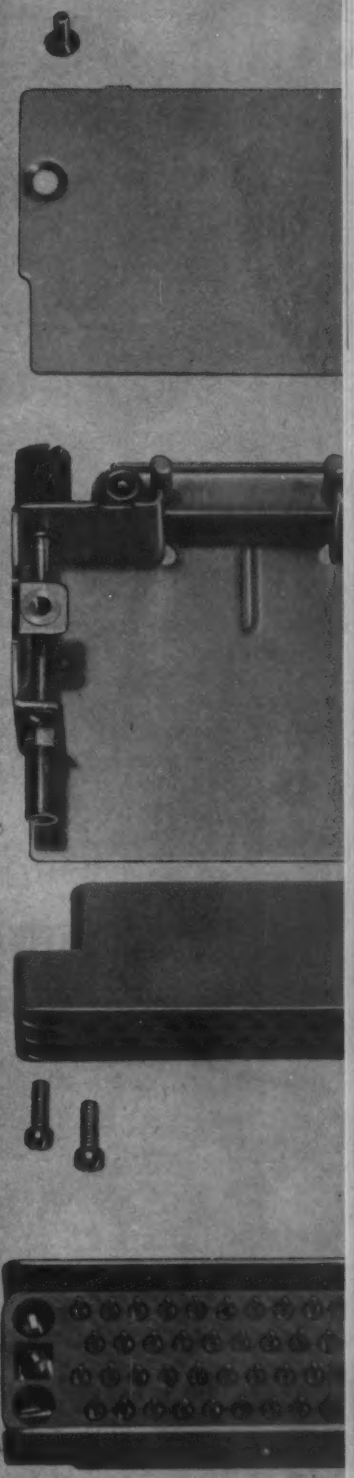
CIRCLE NO. 27 ON INQUIRY CARD

LOOK INTO CEC CONNECTORS

. . . see why they're guaranteed to give you highest reliability

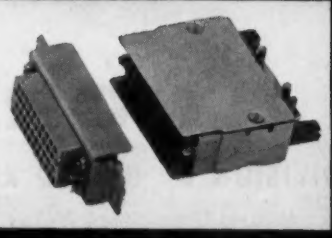
The only thing you can't see for yourself is CEC's design and manufacturing experience in multi-contact rectangular connectors with snap-in contacts. That experience is well represented in the following features:

- Portal-hood speeds final assembly, permits full inspection of interior.
- Firmly attached cable clamp secures all wires to each other and to the connector.
- Jackscrews lock plug and receptacle together to withstand 50 g shock and cycling from 54 to 2,000 cps.
- Sturdy hood holds the insulator block... houses and protects the mated connector.
- Insulator block has deeply recessed contact openings and an unusually long insulation creepage path.



Yes, we can deliver. The 50-contact unit shown here is among many CEC types with 26, 34, 42, 50, 75 and 104 contacts.

For complete information, write for Bulletin CEC 4004-X24. Ask about CEC connector designs to your exact requirements.



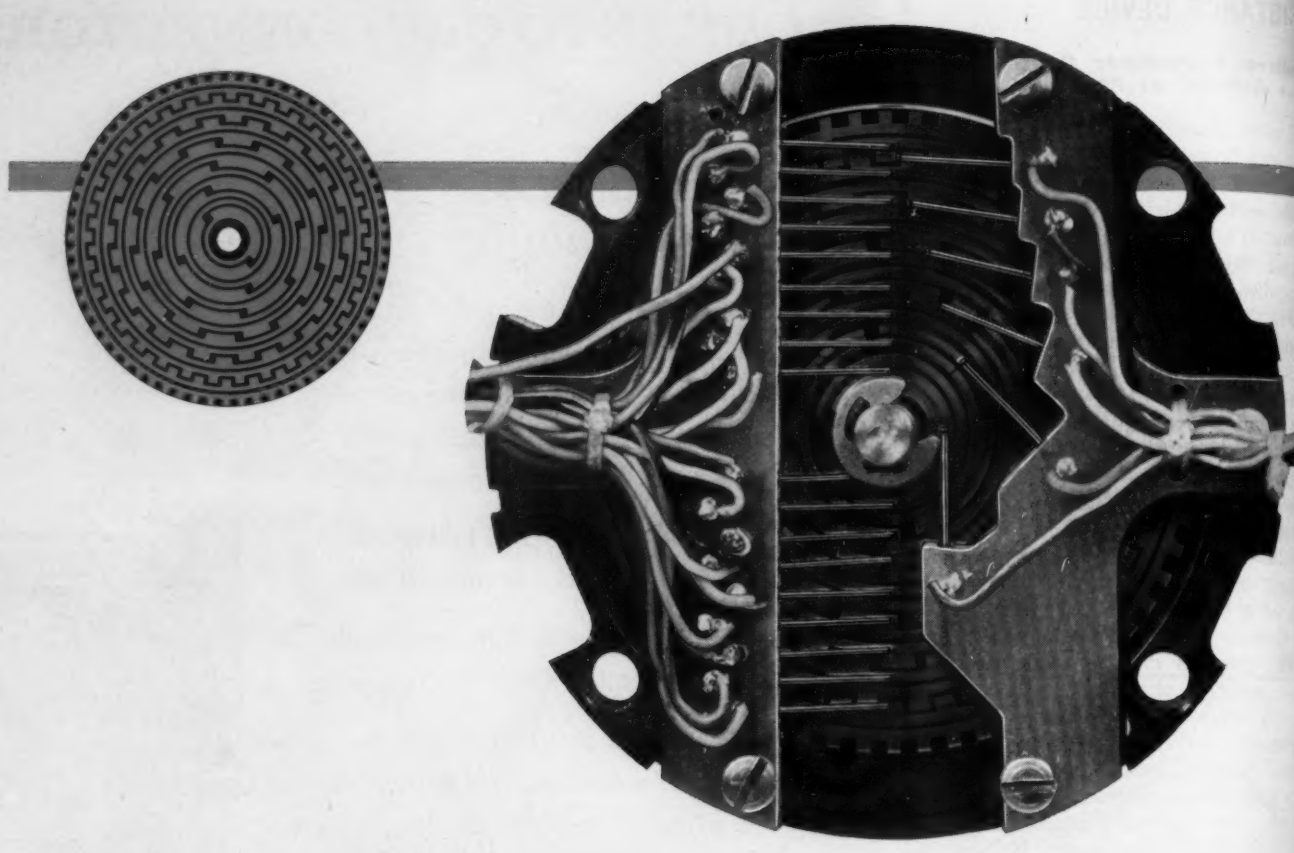
Four-prong retention springs on pin and socket allow each contact to snap into insulator blocks easily, yet resist an axial pull of more than 20 lb. Inspection holes provide built-in quality control, permit visual checking of each wire for proper contact prior to assembly of connector.

Electro Mechanical Instrument Division

CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · FINER PRODUCTS THROUGH IMAGINATION



Norden converters eliminate external electronics, simplify circuitry by non-ambiguous, self-selecting brush design

Unique Norden self-selecting V-scan pattern translates analog input into digital electrical representation by means of self-contained, non-ambiguous, dual brush-selection logic. This Norden design

- offers the *only* shaft position encoders to qualify under MIL-E-5422D and MIL-E-5272A.
- simplifies total system design and reduces cost.
- has provision for automatic error-monitoring.
- has precision brushes, fewer components and unambiguous output assuring highest reliability.
- saves space . . . ideal for subminiature techniques.
- permits direct parallel readout accurately following the shaft position even at highest shaft speeds.
- has longer life because no load current-carrying brush ever commutates; insulation of only 19% of disc area minimizes brush wear and insulation dust.

MODEL NO.	TOTAL COUNT	REVOLUTIONS PER COUNT	(1 PART IN) ACCURACY
ADC-ST7-BNRY	2^7	1	128
ADC-13-BNRY	2^{13}	64	8192
ADC-19-BNRY	2^{19}	4,096	524,288
ADC-ST8P-BNRY	2^8 (with parity)	1	256
ADC-ST9-BNRY	2^9	1	512
ADC-ST10-BNRY	2^{10}	1	1024

These Norden self-selecting V-Brush encoders fit a wide variety of applications. For complete specifications and drawings, call Milford, Connecticut, TRinity 4-6721. If your requirements demand special variations, Norden engineers will work out a custom design.

NORDEN

DIVISION OF UNITED AIRCRAFT CORPORATION

Milford Department, Wiley Street, Milford, Connecticut

CIRCLE NO. 28 ON INQUIRY CARD

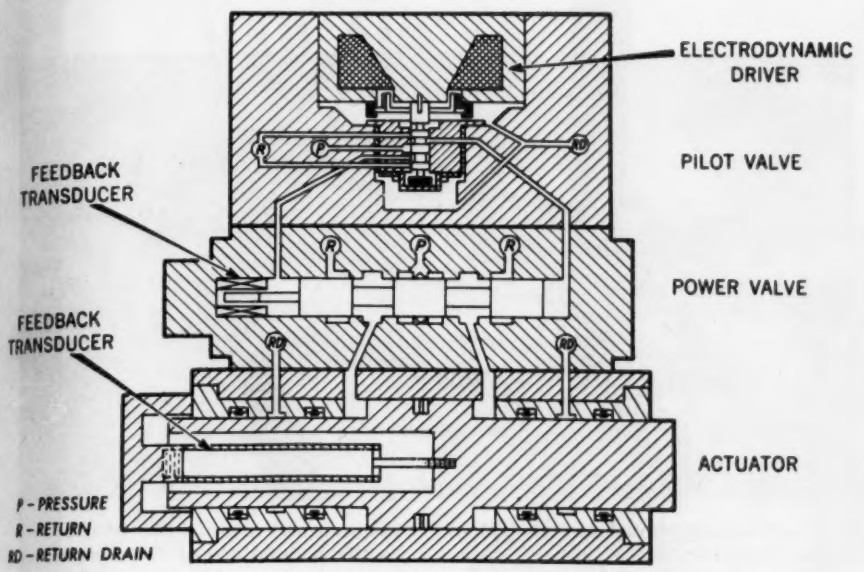


Fig. 1 Schematic of one of MB Electronics' hydraulic vibration exciters.

VIBRATION TESTING

Electrohydraulic Systems Combine High Force And Long Strokes

Vibration test machines are being asked to produce extremely long strokes and much higher forces for certain applications. According to Jack Trevett, Senior Project Engineer, at MB Electronics, New Haven, Conn., hydraulics should be given serious consideration in applications requiring an unusually large output of force in the low to medium frequency range for testing complete system packages. The long stroke capability of an electro-hydraulic exciter makes it especially useful in reproducing the special environmental conditions associated with low vehicular frequencies and in simulating actual terrain profiles.

MB Electronics, Div. of Textron Electronics, Inc. has developed 27 models in all, producing 1000 to 100,000 pounds force output for vibration fatigue and shock testing as well as for steady force applications. The new machines operate in the low to intermediate frequency range, 0 to 800 cps, and range in stroke from ¼ in. D.A. to 9 in. D.A.

Each electrohydraulic loading system consists basically of one or more exciter heads, a primary hydraulic power supply, and an integrated, all inclusive electronic control console. Hydraulic power supply includes motor, pump, accumulators, oil reservoir, heat exchanger and other accessories to insure a constant, ample and smooth flow of fluid power. The exciter's output element is a double acting hydraulic actuator, with piston area and drive rod varying according to the force and stroke rating of the exciter. Motion of this actuator is controlled by a servo valve, which in turn is controlled by electrical drive and control signals from the control console.

Input signals are generated by a master oscillator housed in the control console. These signals are fed to the electronic servo control amplifier, where they are combined with the feedback signals from the hydraulic exciter. This drive signal, after power amplification, is supplied to the driver coil of the small electrodynamic exciter which drives the first spool of the two-stage servo valve. Pilot stage (or preamplifier) of the servo valve transforms electrical variations into variations of fluid flow, which are in turn reproduced by the hydraulic power stage (or amplifier) of the valve. Actuator velocity is proportional to oil flow and varies with the electrical input signal.

Circle No. 106 on Inquiry Card

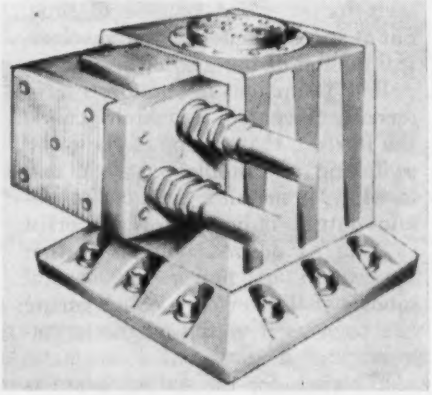
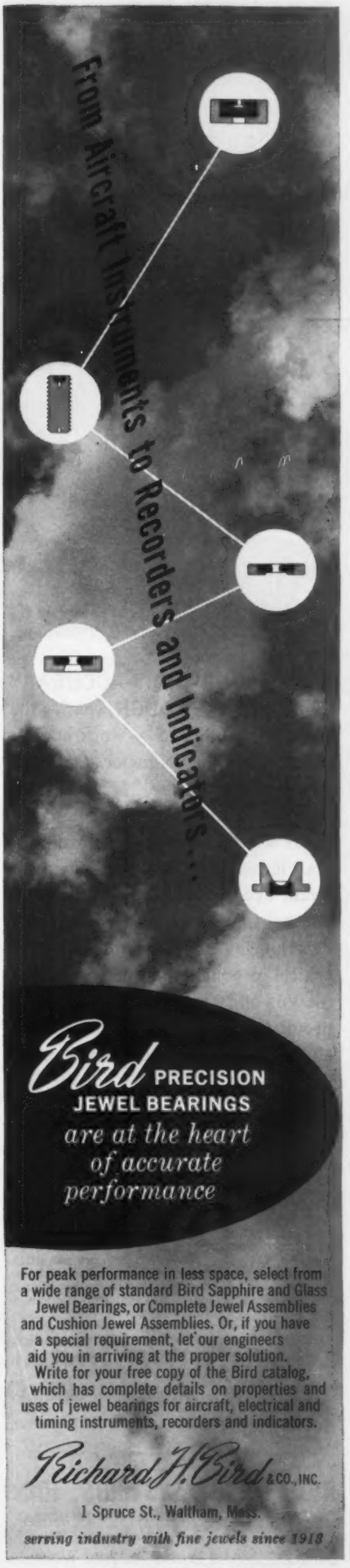


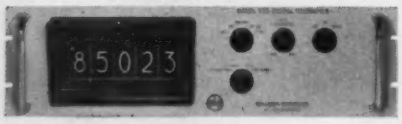
Fig. 2 External view of MB Electronics' hydraulic vibration exciter.


From Aircraft Instruments to Recorders and Indicators . . .
Bird PRECISION JEWEL BEARINGS
are at the heart of accurate performance
For peak performance in less space, select from a wide range of standard Bird Sapphire and Glass Jewel Bearings, or Complete Jewel Assemblies and Cushion Jewel Assemblies. Or, if you have a special requirement, let our engineers aid you in arriving at the proper solution.
Write for your free copy of the Bird catalog, which has complete details on properties and uses of jewel bearings for aircraft, electrical and timing instruments, recorders and indicators.
Richard H. Bird & CO., INC.
1 Spruce St., Waltham, Mass.
serving industry with fine jewels since 1918

CIRCLE NO. 29 ON INQUIRY CARD

NEED MORE THAN FOUR?

Only Voltmeter with the Factual Fifth Figure



WHEN FOUR-DIGIT ACCURACY JUST ISN'T ENOUGH, specify the five-digit NLS V35 — world's most accurate digital voltmeter. Only the V35 gives you the "factual fifth figure" . . . full five-digit resolution of 0.001%. Here is the instrument for your measuring jobs demanding maximum accuracy — automatic missile checkout, readout and printout in data logging and computer systems, critical production inspection. Only the V35 offers you the benefits of "no-needless-nines" logic — greater reliability, increased speed, longer parts life. Contact NLS today for the full story.

V35 Specifications: Measures DC voltage from ±0.0001 to ±999.99; DC voltage ratio from ±00.001% to ±99.999% . . . DC voltage accuracy is ±0.01% of reading or ±1 digit . . . overall accuracy for voltage ratio is ±0.005% of reading or ±1 digit . . . "factual fifth figure" — 0.001% resolution . . . transistorized "no-needless-nines" logic . . . plug-in modular construction . . . simple external connections for AC/DC converter, pre-amplifier and data logging accessories . . . one-package design — 5¼" high — for standard rack mount . . . automatic selection and indication of range and polarity . . . interchangeable plug-in stepping switch-resistor assemblies sealed in oil . . . $3,750.00, complete. Available in four-digit model for $3,150.00, complete.

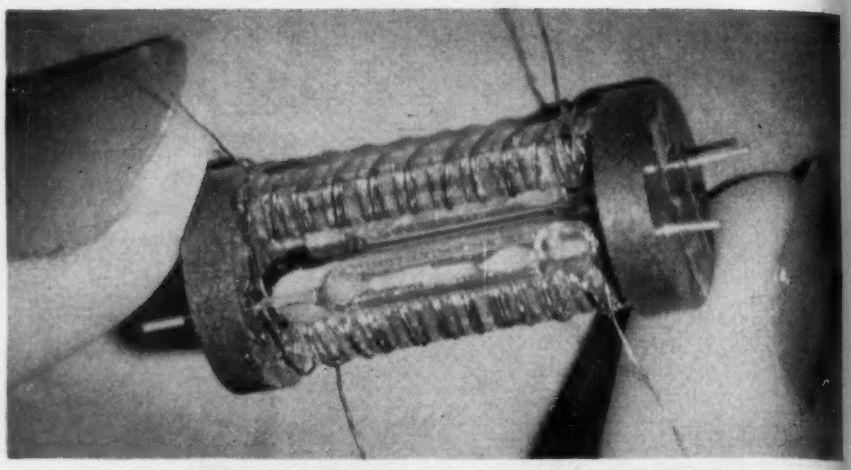
Originator of the Digital Voltmeter

non-linear systems, inc.

DEL MAR (SAN DIEGO), CALIFORNIA

NLS — The Digital Voltmeter That Works . . . And Works . . . And Works!

CIRCLE NO. 30 ON INQUIRY CARD



The ferreed, developed at Bell Telephone Laboratories, is a very fast electro-mechanical switch with metallic contacts requiring no holding power. In the two-branch ferreed pictured, two ferrite bars, two glass-sealed magnetic reed switches, and two plastic end-pieces comprise the magnetic circuit. Non-conducting electrically, the plastic end-pieces magnetically couple the ferrite bars to the magnetic reed switches, at the same time providing a good structural support for the assembly. The passage of magnetic flux through the movable metallic members of the reed switch closes a circuit. Control pulses of five microseconds through the windings on the ferrite will switch the magnetic field.

FERRITE, REED SWITCH

Microsecond Memory Drives Metallic Contacts

Magnetic materials that can be quickly switched between two alternate states have been widely used as "memories" for storing information in digital computers. Useful output from these elements has generally been limited, however, to electrical signals of a transistory character.

In conventional electromagnetic relays, on the other hand, continuous electrical currents have been used to open and close metallic contacts for extended periods of time, but at speeds limited by the mechanical motion of the moving parts.

Bell Telephone Laboratories have recently invented a switch, called the ferreed, that combines the rapid switching of bistable magnetic material with metallic contacts to obtain output indications that persist as long as desired without further application of power. In several models of the device, a cobalt ferrite has been used as the magnetic material and a glass-sealed magnetic reed switch for the output contacts —hence the name "ferreed."

In operation, the magnetic material is switched by a magnetomotive force applied, typically, as a five-ampere current pulse in a thirty-turn winding. The magnetic structure permits switching by current pulses of widely variable character. Control pulses as short as five microseconds will switch the magnetic material, resulting in the passage of magnetic flux through the movable members of the reed switch. Actual closure of the contacts is delayed by inertia of the reeds for several hundred microseconds.

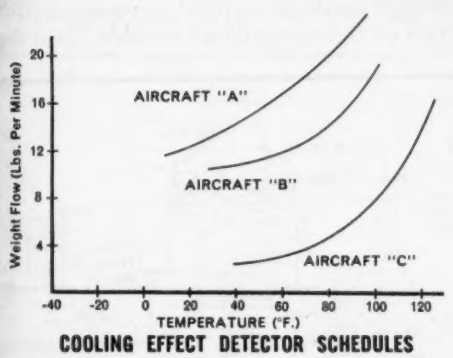
Release of the contacts is brought about by cancellation of the magnetic flux through the reeds, as the result of another five-microsecond switching operation. Opening of the contacts requires less time than the closing operation.

Several new magnetic materials have been synthesized for use in developmental models of the ferreed. Among these are ferrites exhibiting characteristic midway between permanent magnets and computer memory materials, and ferrite suspensions in plastic "tailor-made" for specific magnetic, electrical and mechanical properties. The reed switch is similar to a type used in standard electromagnetic relays for the past decade.

VĀP-AIR cooling effect detector

Senses the actual cooling effectiveness of the air being delivered over electronic components . . . regardless of volume, density or temperature delivered.

A unique and proven device — lightweight, positive, accurate . . under all conditions.



COOLING EFFECT DETECTOR SCHEDULES

Area of adequate cooling lies above each curve. Area of deficient cooling lies below and to right of each curve. Since the Cooling Effect Detector is adjustable, it can be matched to each curve.

VĀP-AIR — SPECIALISTS IN AIRCRAFT TEMPERATURE CONTROLS FOR NEARLY 20 YEARS

Entire systems and a complete line of sensors, electronic controls and precise voltage regulation, electropneumatic and electromechanical valves, advanced in-line valves and regulators, electric power controllers and heat exchange equipment — for aircraft, missiles and ground support.

for complete technical information and applications write:

VĀP-AIR AERONAUTICAL PRODUCTS DIVISION
VAPOR HEATING CORPORATION, DEPT. 62-D
80 East Jackson Blvd., Chicago 4, Illinois

NEW YORK • ST. PAUL • DENVER • WASHINGTON • PHILADELPHIA • ATLANTA
SAN FRANCISCO • HOUSTON • RICHMOND • LOS ANGELES • ST. LOUIS

Please send me complete information on the Vāp-Air Adjustable Cooling Effect Detector.

NAME_____

FIRM_____

ADDRESS_____

CITY, ZONE, STATE_____

CIRCLE NO. 31 ON INQUIRY CARD

PROCESS CONTROL

Seven Systems for Solving Control Problems

Few process control problems are completely new; most of them can be solved by minor variations of basic circuits. Developing this idea in a paper given at the Winter Instrument-Automation Conference and Exhibit in Houston, Texas, C. L. Mamzic, Manager of the Application Engineering Dept. of the Moore Products Co., Philadelphia, Pa., described 7 tried and proved multiple loop systems which he said could be used to solve most of the control problems that single loop systems cannot handle adequately.

1. CASCADE CONTROL

The term "cascade," as used here, means a system which employs two (or more) controllers connected in series and operationally interlocked, to provide closer control of a process variable by eliminating the effect of load changes on the manipulated variable. Because an ordinary feedback control system acts only after an error develops, the system cannot adjust to load changes which affect the manipulated variable until the effect of such load changes reflects itself in a change in the controlled variable. Obviously, on processes having longer lags, the effect will be more pronounced, because the load change goes undetected for a longer period of time. For this reason, cascade control is particularly effective on long-time-constant processes.

Figure 1 shows a single-loop feedback control system applied to a shell-and-tube heat exchanger, to control the outlet temperature of the process fluid. Figure 2 shows how cascade control would be applied to eliminate the effect of load changes on the manipulated variable (heat input).

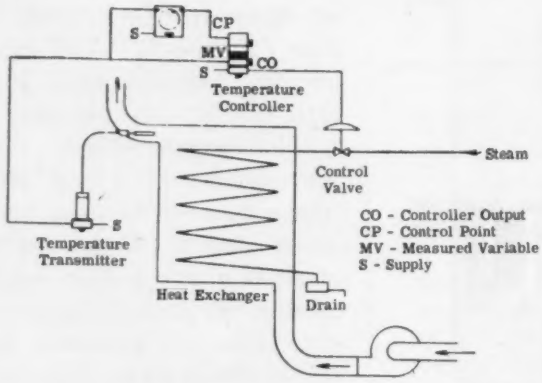


Fig 1 Single-loop feedback control, on heater-outlet temperature. A transmitter measures the outlet temperature and signals the controller—which, in turn, manipulates the valve, to vary the flow of steam to the heat exchanger. In this system a problem exists if the steam supply line pressure fluctuates as it does in most installations. Every time a load change occurs on the steam supply line, the upstream pressure on the steam control valve changes, resulting in a change in heat-input rate to the process. If the outlet-temperature transmitter could quickly sense the effect of this change, the controller could take immediate corrective action—and there would be no serious problem. However, because of transfer lags and the transportation delay, a considerable interval elapses between the time the heat input rate changes and the time outlet temperature transmitter detects any change. All during this interval, an incorrect amount of heat is being added to the process, and even though the controller finally begins to take corrective action, the outlet temperature continues to change. Just as it takes a long time to detect a change in outlet temperature, it takes a long time to restore control once a change is detected.

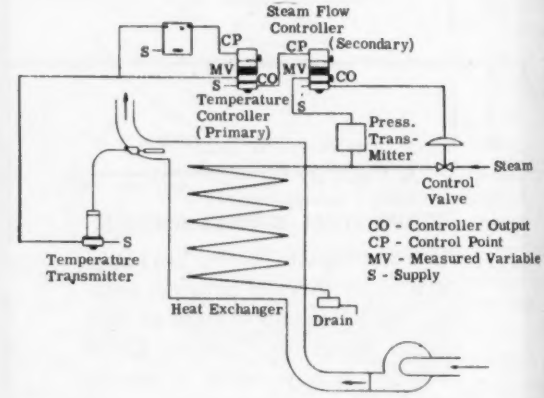


Fig 2 Cascade control on heater-outlet temperature. Here a temperature transmitter and controller similar to those of Fig 1 are used to measure and control outlet temperature, however, instead of connecting the output of the outlet temperature controller to the control valve, the output becomes the control point signal to a second controller, directing it to maintain a designated heat input rate to the exchanger. Since heat input rate is a function of the steam pressure in the heat exchanger, the second controller, more specifically, is set to control the heat exchanger steam pressure. With this system, as quickly as a load change in the steam supply header begins to affect the steam pressure in the exchanger, the secondary controller goes to work, readjusting the control valve to maintain the same steam pressure in the heat exchanger as existed before the load change developed. Action of the secondary controller in this case completely eliminates the effect of load changes on the manipulated variable. The primary controller, spared from this task, concentrates only on keeping up with variations in process fluid flow, process fluid inlet temperature, and radiation losses from the vessel.

Other examples of cascade control applications are:

- Fractionating column temperature control, with a temperature controller setting either a steam pressure or a steam flow controller.
- Batch reactor temperature control, with a batch-temperature controller setting a jacket-temperature controller.
- Fired heater temperature control, wth an outlet temperature controller setting a fuel-rate controller.
- On-line closed loop computer control systems, with a computer setting individual process-variable controllers.

2. IMPULSE FEEDFORWARD WITH FEEDBACK CONTROL

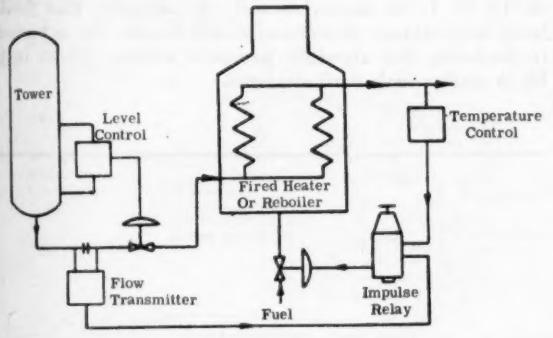
In this system an otherwise normal feedback control loop is independently impulsed, causing it to anticipate a change in load which will ultimately affect it, but which the feedback loop alone would not otherwise sense until the process variable deviated from the control point. The impulse is generated by a relay connected in the feedback loop. This relay receives an independent signal proportional to the load, and superimposes, on the feedback loop, a signal proportional to rate and direction of change in load. The term "feedforward" applies, because the system is made to recognize that a load change has occurred, even before the load change begins to affect the process. Impulse feedforward has two major uses:

- It can provide closer control on certain processes which involve transportation delay and transfer lags.
- It can provide stability in processes which involve two or more closely interwoven control loops.

Figure 3 shows the use of impulse control on a fired heater, or re-boiler. Figure 4 shows how impulse control is applied to a hydrogen adsorber, to provide stable operation where two fast, interacting control loops tend to make the process unstable.

Other examples of the use of impulse control are:

- Two-element boiler drum level control in which an impulse circuit is used to compensate for the "shrink" and "swell" condition which occurs as the steam flow suddenly changes.
- Propane vaporizer control, in which the impulse relay is used to counteract the effect of interaction between a vapor pressure controller and a steam pressure controller.

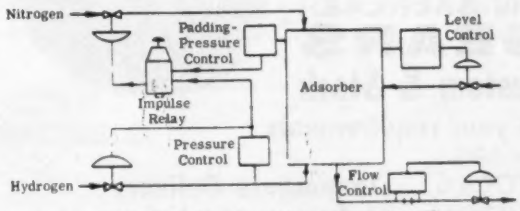


Impulse Relay Output = Temperature Controller Output + Impulse Component Generated By Change In Product Flow.

Fig 3 Heater-outlet temperature control, with impulse feedforward action. The function of the system is to control heater outlet temperature by setting the rate of fuel flow to the heater. Flow of product to the heater fluctuates as tower level changes. However, because of the transportation lag and the transfer lag the temperature controller does not sense the effect of flow changes until after several minutes have elapsed. It is only after the outlet temperature is affected that the controller can take corrective action. All during this period, however, an improper amount of heat is being added to the process, with the result that the outlet temperature continues to change, even after the controller begins to take corrective action. Adding the impulse circuit to the basic feedback loop, minimizes error and considerably improves control. The impulse relay transmits the output of the controller to the control valve in a 1:1 ratio; and at the same time superimposes on this output signal a component, proportional to rate and direction of change in product flow. An impulse based on change in product flow, therefore, is fed forward to the feedback control loop, by the action of the relay. The impulse has the effect of modifying the fuel flow, in anticipation of the affect which the change in product flow will have on the outlet temperature.

3. PREDICTIVE FEEDFORWARD WITH FEEDBACK

This system is, essentially, an open-loop control circuit with a closed feedback loop superimposed. It can be used where there is a predictable relationship between load changes and the required value of manipulated variable (or position of the control valve). The open-loop system acts simultaneously with load changes to provide an optimum rate of correction. On the other hand, the feedback loop, which acts only after an error develops, serves simply to trim the system, to correct for limitations inherent in open-loop control.



Impulse Relay Output = Padding Pressure Controller Output + Impulse Component Generated By Change In Hydrogen Pressure Controller.

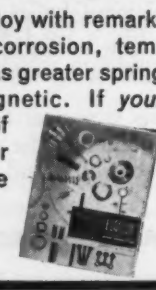
Fig 4 Hydrogen adsorber control with impulse feedforward, used to prevent inter-action. A nitrogen blanket is maintained above a bed of process liquid, which adsorbs hydrogen. If the rate of hydrogen adsorption suddenly changes, the level (and, consequently, the nitrogen-padding pressure) changes. Because of the interaction between the hydrogen-pressure-control circuit and the padding-pressure-control circuit, and also because of the lags in the padding-pressure-control circuit, there is a tendency for the controls to overcorrect—causing "hunting." Through addition of an impulse relay to the padding-pressure-control line any sudden change in hydrogen-pressure-control alters the nitrogen pressure simultaneously, causing the nitrogen-pressure-control system to anticipate the nitrogen pressure change, which would eventually result from a change in rate of hydrogen adsorption. This circuit, therefore, gives both closer control of hydrogen adsorption and more stable operation of the adsorber.

LET ELGIN MAKE THEM WITH ELGILOY!

• Power Springs • Coil Springs • Drive Bands

. . . and Ball Bearings, Torsion Bars, Stamped or Machined Parts, Cable, etc.

Elgiloy is a cobalt spring alloy with remarkable properties: Resists corrosion, temperature, set and fatigue; has greater spring effectiveness, is non-magnetic. If *your* components require any of these properties, write or call Elgin today. Ask for the Elgiloy Data Book.

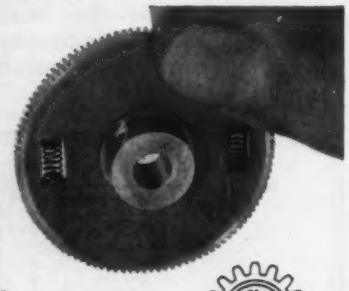


Abrasives Division
ELGIN NATIONAL WATCH COMPANY
ELGILOY DEPT.
ELGIN, ILLINOIS

CIRCLE NO. 32 ON INQUIRY CARD

Now Available!

PRECISION CLASS I & II anti-BACKLASH GEARS
Custom & Stock
to your requirements
1 or 1,000



STOCK . . . Immediate Delivery
CUSTOM . . . Approx. 3 weeks prototype

STOCK SPECIFICATIONS

Precision Class I and II anti-backlash gears: ⅛" face width, 48, 64, 72, 80, 96 or 120 diametrical pitch, 14½° or 20° pressure angles, diameters from ⅜" to 2". Available in 245T aluminum with solid or clamp type 303 S.S. hubs with choice of 0.125", 0.1875" or 0.250" bores.

CUSTOM AB GEARS TO YOUR SPECS AND DRAWINGS

FREE!

Send for supplements to DYNACO E88 Catalog. Shows complete line & specs. on precision stock differentials and new, miniaturized line of precision stock gears.

DYNAMIC GEAR CO. INC.
AMITYVILLE, NEW YORK

CIRCLE NO. 33 ON INQUIRY CARD

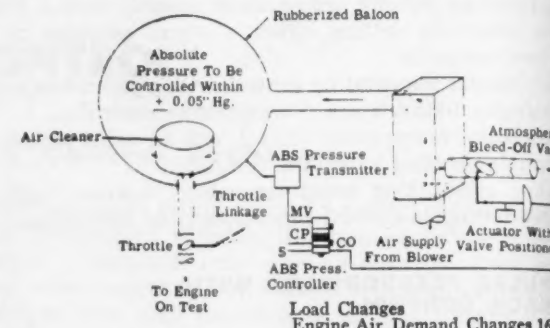


Fig 5 Single-loop feedback control of inlet-air pressure on an engine test stand. Air is supplied to a windbox by a blower, and the balloon pressure is controlled by venting part of the flow to atmosphere, through the control valve. This system would be adequate, if the load changes were not excessive. In this application, however, the load change is rather severe. When the throttle is suddenly opened, the air flow demand of the engine increases by a ratio of 16 to 1, in approximately 2 seconds. The feedback loop alone, therefore, could hardly be expected to maintain the absolute pressure within ±0.05 inch Hg A under such load changes.

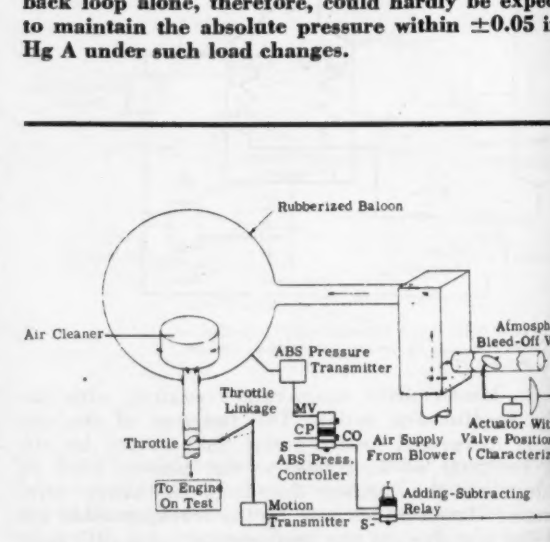


Fig 6 Inlet-air pressure control, with predictive feedforward action. The basis for this multiple-loop system is the fact that a predictable relationship exists between throttle position and required bleed-off valve position. As the throttle opens, the bleed-off valve closes. This characteristic of the system permits setting up an open-loop control circuit, consisting of a motion transmitter, a 1:1 ratio adding relay, and a characterized positioner-actuator on the bleed-off valve. The 1:1 relay transmits the signal from the motion transmitter to the bleed-off valve position. (Action of the open-loop circuit is similar to that of a mechanical linkage between the throttle and the bleed-off valve.) With the feedback loop superimposed on the open-loop system by means of the adding relay, a trimming action is added to bring the system into final adjustment.

Figure 5 shows how an ordinary single-loop feedback control system would be set up to control absolute pressure on an engine test stand. Figure 6 shows how a predictive feedforward loop is combined with the feedback loop of Fig. 5 to maintain pressure control under conditions of severe load changes. Predictive feedforward action with feedback control is employed in some types of three-element drum level control, on boilers.

4. CASCADE WITH RATIO PREDICTIVE FEEDFORWARD

As the name implies, this type of multiple-loop system provides a combination of cascade control with predictive feedforward action. The feedforward portion of the circuit provides immediate adjustment for load changes, while the feedback loop provides the final trim required for accurate control. Two examples of this type of control are described in Figs 7 and 8.

Figure 7 shows how the heat exchanger shown in Fig 1 can be instrumented, to provide immediate compensation for variations in product flow as well as for load changes on

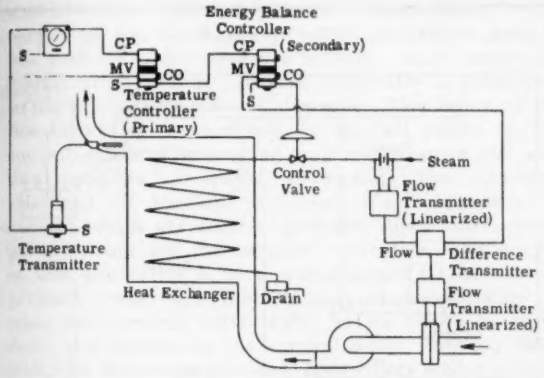


Fig 7 Cascade heater-outlet temperature control, with ratio predictive feedforward action. As in Fig 2, the primary controller sets the control point of the secondary controller, to maintain outlet temperature at the desired value. The secondary controller in this case, however, functions to maintain an energy-balance relationship between flow of product and flow of steam. Obviously, in this process, if the product flow increases, the steam flow must increase. Relationship of steam flow to product flow is obtained by metering the two flows and measuring their differential. Output of the differential transmitter is the measured variable signal for the secondary controller. In operation, the primary controller commands the secondary controller to maintain a certain energy-balance relationship. If the product flow suddenly changes with respect to steam flow, the energy balance controller immediately acts on the steam control valve to maintain the required relationship between product flow and steam flow. This action takes place long before the outlet temperature becomes affected. If, on the other hand, the product flow is steady and the steam flow fluctuates (because of changes in load on the steam supply line), again the energy balance controller acts to maintain the relationship between steam flow and product flow called for by the primary controller. The primary controller trims the system, to take into account the limitations in the secondary (open loop) portion of the system, which provides the feedforward action.

BIG

IN PERFORMANCE AND RELIABILITY

TINY IN SIZE

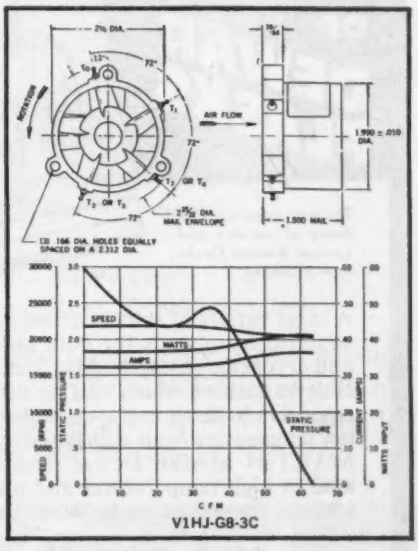
V LINE

Miniature Vane Axial Blower

This is the newest development in EAD's growing family of "V-LINE" Vane Axial Blowers. Maximum air delivery plus top efficiency (watts in against air out) in an extremely compact package – just 1.5" in total length, less than 2" in diameter. The unique mechanical and aerodynamic design incorporates EAD's highly-reliable 1"-diameter motor for highest fan speeds and life in excess of 1000 hours at 125°C. In addition to 2-pole characteristics listed, there are 4 and 6-pole designs and models for operation from 1600-cycle and variable frequency power sources. Meets MIL-E-5272A, MIL-E-5400B, other specifications. Write for complete data on this and other "V-Line" models.

TYPICAL CHARACTERISTICS

- 115 volts, 400 cycles single or three phase
- 19,000 rpm nominal
- 65 CFM at 0" SP
- 35 CFM at 2.3" SP
- 37-40 Watts
- 1.5" total length 1.990" housing dia.
- Available with:
  1. Leads
  2. Terminals on mounting flange
  3. Terminals on housing
- Weight, 4.3 oz.



EAD

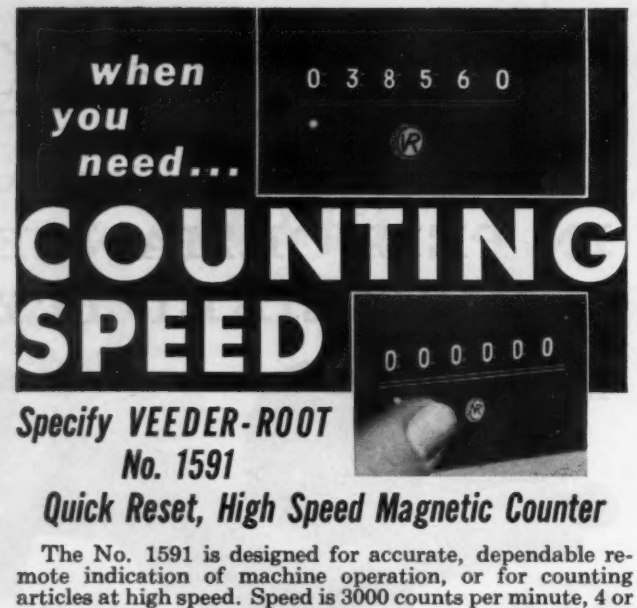
Rotation is a science at

EASTERN AIR DEVICES, INC.

SUBSIDIARY OF NORBUTE CORPORATION

353 CENTRAL AVENUE, DOVER, NEW HAMPSHIRE

CIRCLE NO. 34 ON INQUIRY CARD


when you need...
0 3 8 5 6 0
COUNTING SPEED
0 0 0 0 0 0
Specify VEEDER-ROOT No. 1591
Quick Reset, High Speed Magnetic Counter
The No. 1591 is designed for accurate, dependable remote indication of machine operation, or for counting articles at high speed. Speed is 3000 counts per minute, 4 or 6 figures, manual or electrical reset, and made for panel mounting. Maximum panel area required is: 1.7" x 2.1" for four figures and 1.7" x 2.8" for six figures. The 1591 is available from stock.
Send for Veeder-Root Technical Information. Complete catalog data will be sent to you at once and application assistance is available from a Veeder-Root Counting Engineer if desired. Write or call today.
Veeder-Root
HARTFORD 2, CONNECTICUT
"The Name that Counts"
CIRCLE NO 35 ON INQUIRY CARD

Announcing
A NEW 54-PAGE CATALOG OF DEWAR FLASKS
MARTIN-MADE
CATALOG
DEWAR FLASKS
The most comprehensive listing of standard and special Dewar flasks ever published.
A large variety of standard flasks is listed that can be supplied from stock for both regular laboratory use and cryogenic research. Also included are many possible variations which can be produced to aid your engineers in designing special shapes for work in the low temperature fields with liquid hydrogen and helium. MARTIN-MADE Dewar flasks are highly evacuated at high temperatures and all are manufactured without separation pads. Write today for your copy.
H. S. MARTIN & SON
1916-20 GREENLEAF STREET • EVANSTON, ILLINOIS
SCIENTIFIC GLASSWARE OF SUPERIOR QUALITY
CIRCLE NO. 36 ON INQUIRY CARD

the steam supply line. This type of system is used in certain varieties of three-element drum level control on boilers.

With the advent of continuous-product-stream analyzers, many processes which formerly had to be controlled by open-loop ratio-control systems alone can now include end-point control, by using a system such as shown in Fig 8.

Similar systems can be used to control pH, specific gravity, consistency, and product quality (where the quality can be measured by means of a continuous analyzer). In each case, the end-point is measured and controlled by automatically readjusting a ratio-controller.

5. LIMITING SELECTOR CONTROL

In this type system, decision-making, selector relays automatically and continuously determine which of two or more controllers will have command of the control valve. The system is set up to carry out a certain normal control function until such time as any abnormal condition arises —at which time, it automatically abandons normal control to hold the abnormal condition in check. If the abnormal condition abates, the normal function controller automat-

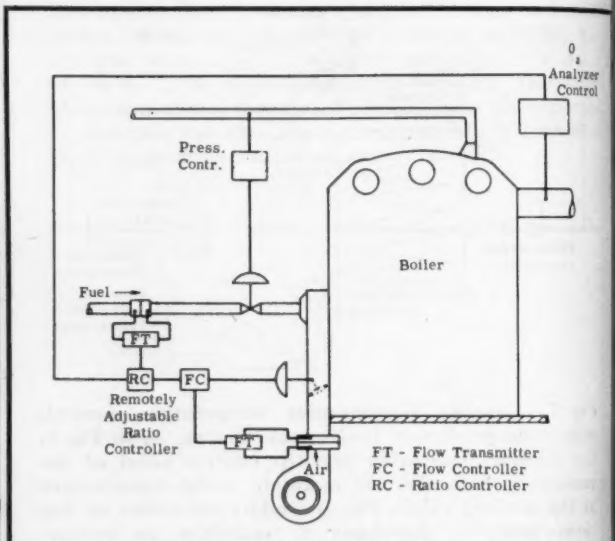


Fig 8 Fuel-air ratio control, with oxygen (excess air) analyzer cascade. Boiler pressure is controlled by adjustment of the fuel flow to the boiler. Economical combustion results from proper ratio of air to fuel. One of the traditional means of controlling air-fuel ratio is to have a ratio controller monitor the change in fuel flow and automatically set the air flow in proper proportion. This, however, is only open-loop control, because the ideal ratio is not a fixed percentage but a varying one which must take into account such variables as fuel analysis, heating value of the fuel, air density, and moisture content of the air. End-point control is applied to such a system by employing an oxygen analyzer to provide continuous measurement of the amount of excess air in the flue gas (a measure of combustion efficiency), and by having this quantity controlled through automatic adjustment of the ratio being maintained, in turn, by the fuel-to-air ratio-controller. It should be noted that the ratio control loop provides the predictive feedforward action which gives immediate response to load changes. The analyzer control circuit only serves to trim the system, asking for slight changes in ratio, as the ideal ratio varies.

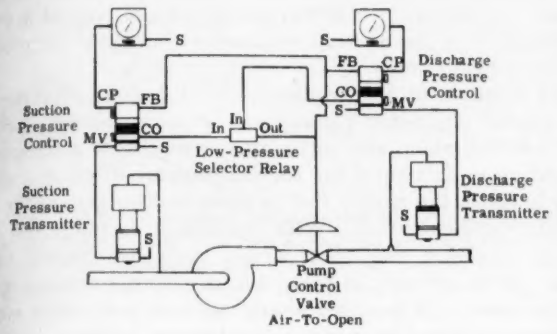
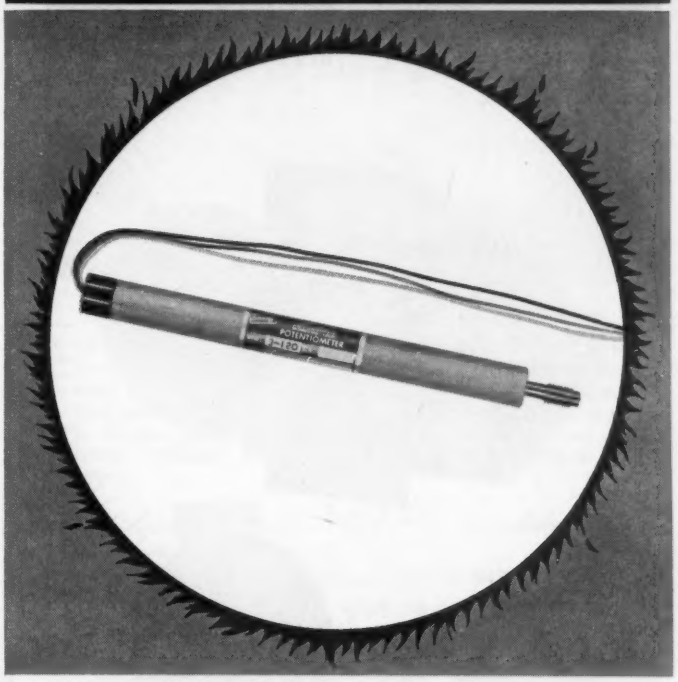


Fig 9 Safety-limiting selector control, on booster pump suction and discharge pressure. The system shown assumes the use of a pneumatically-actuated control valve which operates "Air-to-Open." The output of the discharge pressure controller goes to one port of a low-pressure selector relay, while the output of a suction pressure controller is connected to the other inlet port of the relay. The lower of the two inputs is transmitted, in its full value, to the control valve. The control point setting on the suction pressure controller represents the allowable safe-limit of suction pressure. When operation is normal—with the suction pressure above the control point setting on the suction controller—the output of this controller is at a maximum. (If the suction pressure controller had its way it would want to open the control valve wide, in an effort to bring down the suction to the control point setting.) However, the discharge pressure controller, under normal conditions, will have the lower output signal and will, therefore, have command of the control valve. If something occurs that would drop the suction pressure below the control point, the suction controller would transmit a lower output and the selector relay would transfer command of the valve to it. The suction controller would throttle-down the valve, only as required to prevent the suction pressure from dropping any lower than the control point. Should the suction pressure return to normal (above the control point), control would automatically be transferred back to the discharge pressure controller. The selector relay, in transmitting the lower of the two input signals, acts to give control to that loop which requires the valve to be more nearly closed. In this way, it assures that neither limit, high discharge pressure nor low suction pressure, is exceeded. To obtain maximum effectiveness from this type of control system, the reset feedback signals of all controllers should be connected in common with the output of the selector relay, which is the valve operating signal. With this arrangement, the reset action in the commanding controller is permitted to function normally, while the reset reference in the overridden controller is held at the same value as the reset reference of the controlling unit. This common connection prevents reset saturation, or wind-up, during the time a controller is overridden—and results, instead, in a perfectly smooth and immediate transition of control when it is time for the overridden controller to resume command of the valve.

Edcliff
TRANSDUCERS
SERIES 3



Wirewound Feedback Potentiometers

FOR OPERATION TO 500°F

Edcliff Instruments' Model 3-120 linear motion servo potentiometers are designed for use with hydraulic and electrical actuators in Missile, Aircraft and Remote Control Systems. Only ½ inch in diameter, the new, all metal construction instruments may be installed inside the actuator shaft to conserve space.

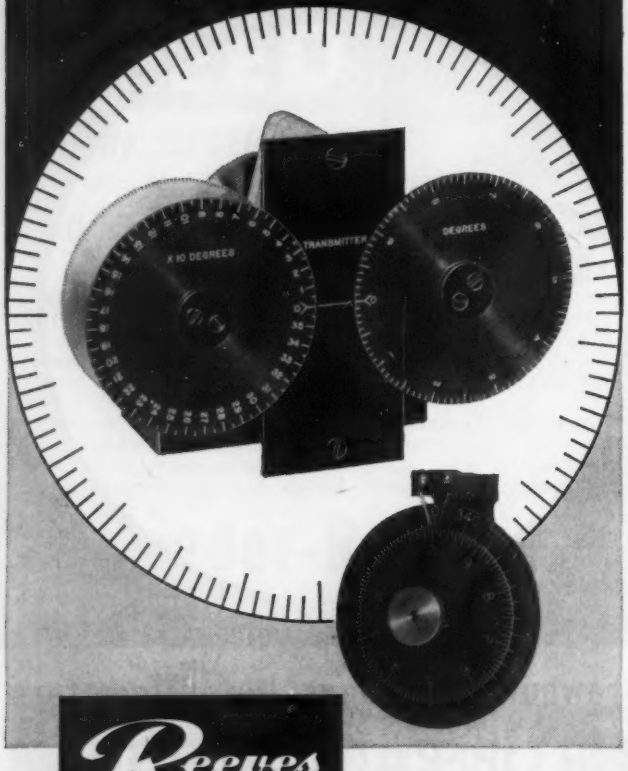
Small Size: Only ½ inch diameter.
Standard Stroke lengths from 1 to 5 inches.
Built for High Temperature Operation to 500°F.
Rugged, insensitive to Shock and Vibration.
All Metal Construction.
Meets or exceeds applicable Mil Specs.
Resistance Ranges from 100 to 50,000 ohms/inch.

Edcliff Instruments has a production model potentiometer for every application. Let Edcliff supply the "feel" for your guidance system. Write today for your free application data catalog.

Edcliff
INSTRUMENTS
1711 South Mountain Avenue
Monrovia, California

CIRCLE NO. 37 ON INQUIRY CARD

READOUT
Reliability



Reeves
INSTRUMENT CORPORATION

PRECISION

DIAL ASSEMBLIES
for computer display applications

Twin Dial Assembly — A high precision unit with very low gear backlash. Ideal for two speed indicator applications. Available from stock in gear ratios of 10:1 and 36:1.

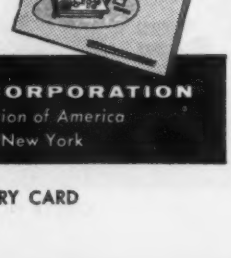
Concentric Dial Assembly — A miniaturized assembly for two-speed applications. Maximum precision with extremely low backlash. Available from stock in gear ratios of 10:1 and 36:1, with or without hand-input knob.

Both models supplied with dial engravings shown. Available on special order: etched dials and anti-backlash gearing which provide readout accuracies to 1 minute of arc.

Expedite DESIGN • PROTOTYPING • PRODUCTION
BY USING **REEVES** SERVO-MECHANICAL PARTS

Dial assemblies are only one product in the COMPLETE Reeves Series of high-precision Servo-Mechanical Parts, recognized by engineers as an industry standard for highest accuracy and reliability.

If you do not have the catalog, write for Data File No. 404.



2RV60

REEVES INSTRUMENT CORPORATION
A Subsidiary of Dynamics Corporation of America
Roosevelt Field, Garden City, New York

CIRCLE NO. 38 ON INQUIRY CARD

ically resumes control. Generally, this type of system is used where a dangerous condition can develop when a normal control function is allowed to proceed unchecked. The system differs from a safety shutdown system in that, when an abnormal condition arises, normal control is overridden only in the amount required to maintain the process within set safe limits.

An example of the application of this type of system is the control of a booster pump in a transcontinental pipeline. Use of single-loop control in this case allows a dangerous condition to develop if the suction pressure drops as a result of a break in the supply line or some malfunction in the upstream booster pump. With insufficient suction the discharge pressure controller would open the control valve wide, in an attempt to bring the discharge pressure up to control point. This action would ultimately result in vapor-lock and eventual burn-out of the booster pump.

To provide against such an eventuality, a safety limit override selector control system is used, as shown in Fig 9.

Limit selector control is also used to: maintain combustion processes within safe temperature limits; limit differential temperatures across heat exchangers (to protect processes); and prevent flooding in tar distillation towers.

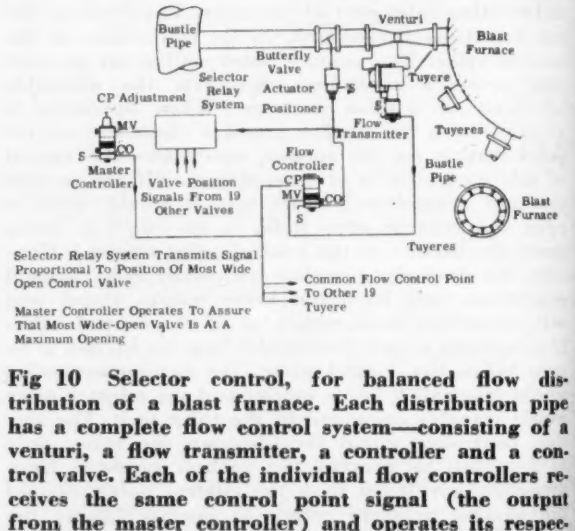


Fig 10 Selector control, for balanced flow distribution of a blast furnace. Each distribution pipe has a complete flow control system—consisting of a venturi, a flow transmitter, a controller and a control valve. Each of the individual flow controllers receives the same control point signal (the output from the master controller) and operates its respective control valve, to maintain the required flow. Obviously, the controller on the distribution pipe that meets with the maximum flow resistance will have its control valve at the most wide-open position with respect to the valves on the other pipes. A selector relay system is set up to determine the position of this most wide-open valve. This information is transmitted as the measured variable signal to the master controller. The control point on the master controller is set so that it acts to maintain this most wide-open valve at the maximum opening (just off the wide-open position stops). Since the output of the master controller is the common control point signal to the individual controllers, obviously, each of the other control valves is throttled down to some degree—to deliver the same flow as is obtained through the most resistant distribution pipe. Hence, all flows are equal—and control valves are as wide-open as they can be, consistent with the flow being equal. This provides maximum economy because the pumping pressures are held down to a minimum.

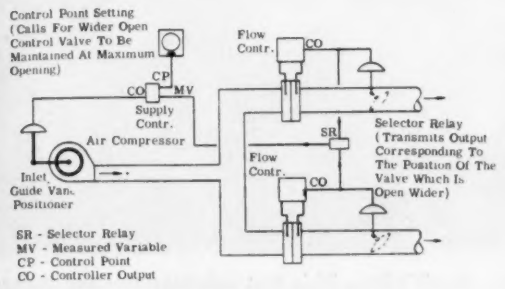


Fig. 11 Selector control with automatic supply adjustment for split loads. The two parallel-connected flow controllers have independently-set control points and each loop meets with a different resistance to flow. The selector relay transmits (to the compressor inlet vane controller) a signal representing the position of the most wide-open control valve. The controller then functions to adjust the compressor inlet vanes (which affect flow and pressure) to keep the most wide-open valve at a maximum opening. The other valve is, of course, throttled down some degree. Though only two parallel-connected branches are shown, any number of branches can be connected in such a system.

6. FLOW DISTRIBUTION SELECTOR CONTROL

This system consists of two or more flow control loops, operating in parallel, with their control points set by a single master controller—and with the system arranged to maintain a set flow distribution pattern while holding the head-loss through the flow control valves at a minimum. The system does not function to provide any specific rates of flow. These are determined, separately, by such factors as the available supply and demand and the flow resistance in the overall process. The system acts only to maintain a given flow distribution pattern at a minimum head loss, regardless of variation in the factors which affect the actual value of the flow.

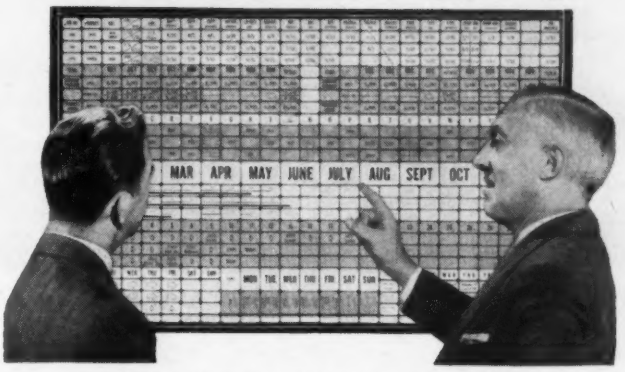
This type of system has been applied to control the distribution of air flow to blast furnaces to prevent erratic operation. A system as shown in Fig. 10 maintains balanced distribution of flow through all distributions while holding the pressure loss through the control valves at a minimum.

7. SELECTOR TYPE SPLIT-LOAD SUPPLY CONTROL

This type system is somewhat related to the flow distribution selector control system, in that the controller functions to keep, at a maximum opening position, the control valve in the most heavily loaded of the two or more parallel branches. In this case, however, the branches may be called upon to maintain independently-set rates of flow, while the master controller adjusts the pump or compressor so that it furnishes just sufficient pressure to satisfy the most highly loaded branch. In so doing, it automatically provides sufficient pressure to satisfy all other branches connected in parallel. The object of the system is to obtain maximum economy of operation. It is particularly applicable to control of large compressors, where operating costs are directly related to pumping pressures Fig. 11.

This type of system is used mainly in applications involving a single air compressor which supplies two or more parallel branches. The branches, in some cases, are separate distribution pipes to a single furnace—while in other cases, they are separate lines leading to different processes.

You Get Things Done Better By Seeing What's Happening



BOARDMASTER VISUAL CONTROL

★ Gives Graphic Picture of Your Operations in Color.
★ Facts at a Glance — Saves Time and Prevents Errors.
★ A Simple, Flexible Tool — Easily Adapted to Your Needs.
★ Easy to Use. Type or Write on Cards, Snap on Board.
★ Ideal for Production, Scheduling, Sales, Inventory, Etc.
★ Compact, Attractive. Made of Metal. 500,000 in Use.

Complete Price $49.50 Including Cards

FREE 24-Page ILLUSTRATED BOOKLET AK-40 Without Obligation

GRAPHIC SYSTEMS, Yanceyville, North Carolina

CIRCLE NO. 39 ON INQUIRY CARD

Other packaging available

10 mc–1,000 mc Frequency Response with new INCREDUCTOR® Wideband RF Transformer

FREQUENCY RESPONSE within ±½ db over 20 mc—500 mc frequency range and ±1½ db from 10 mc—1,000 mc.

AVERAGE INSERTION LOSS 1 db between 20 mc—500 mc and 2 db between 10 mc—1,000 mc.

SIZE 1 15/16" x 2¼" x 1 3/16", Hermetically sealed.

AVAILABLE IMPEDANCE RATIOS presently 200 ohms balanced to 50 ohms unbalanced. Other ratios to be announced.

TYPICAL APPLICATIONS Antenna matching, Input and Output matching of broad band push-pull for single ended amplifiers.

MILITARY SPECIFICATIONS On special order.

MAGNETIC COMPONENTS DEPARTMENT

TRAK ELECTRONICS CO.

Division of CGS Laboratories, Inc.

We invite you to write for INCREDUCTOR® Wideband RF Transformer Technical Bulletin No. 460.

52 DANBURY ROAD, WILTON, CONNECTICUT

CIRCLE NO. 40 ON INQUIRY CARD

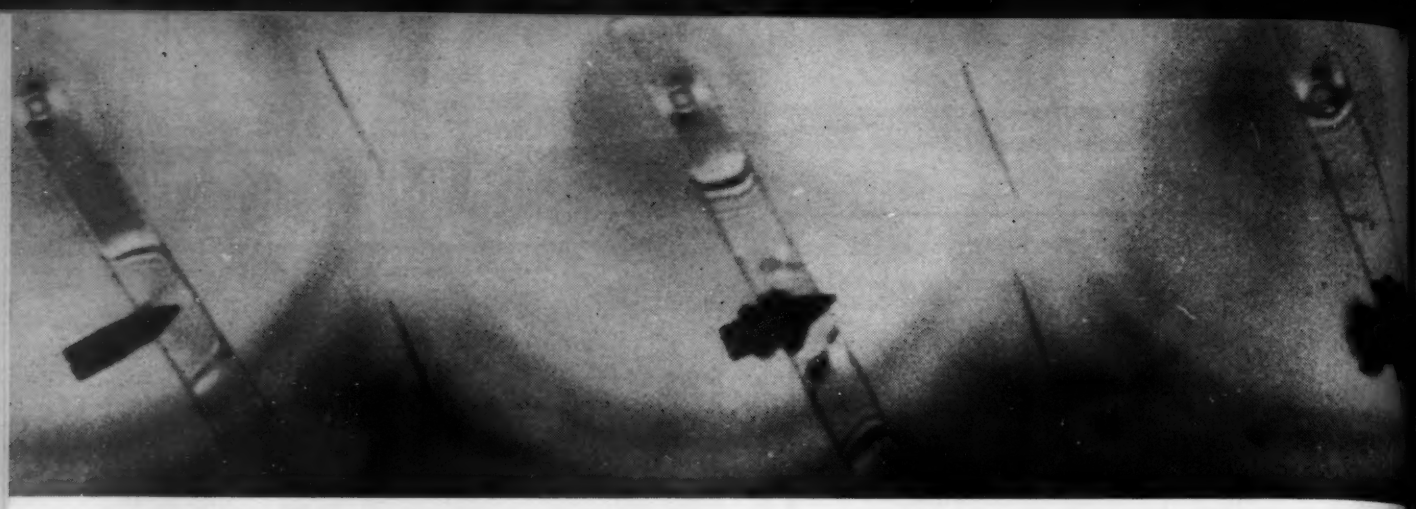


Fig. 1 A 30 caliber bullet was fired at 6500 ft. per second into solid plastic plate. This test substantiates the theory that ve

HIGH SPE

100,000 Magnification of

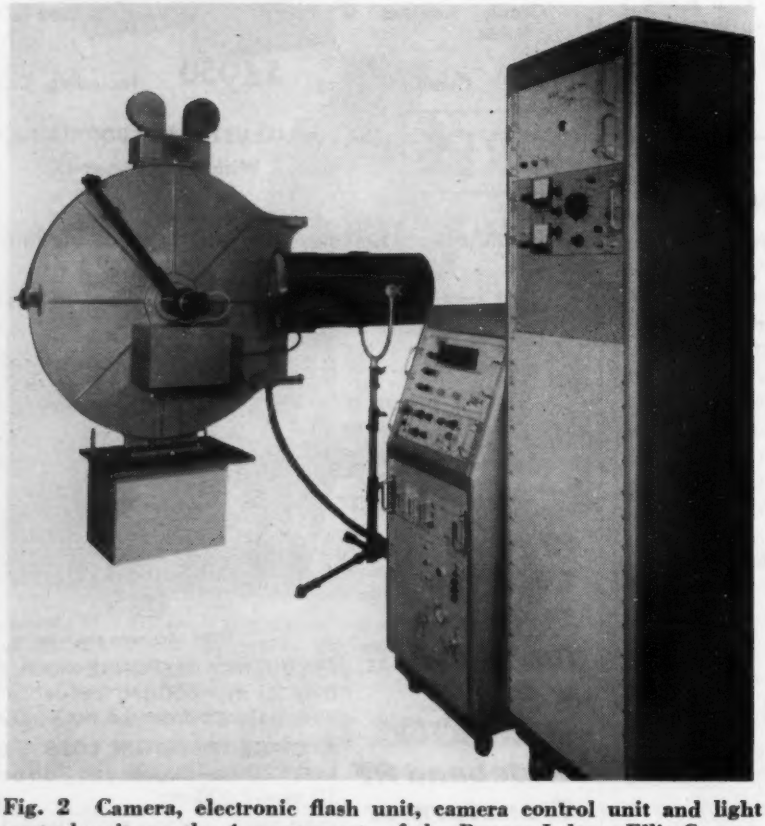


Fig. 2 Camera, electronic flash unit, camera control unit and light control unit are the 4 components of the Benson-Lehner Ellis Camera System. The camera has a film box shaped like a large disk, with the feed and take-up magazines placed at the top. Objective and shutter assemblies are situated at the front end of the disk's center axis, while a high speed air turbine and a revolving mirror are located at the rear end. A radial focusing periscope is attached immediately behind the tubular lens assembly. A standard high luminosity electronic flash unit is mounted on an adjustable pedestal. A standard relay rack cabinet equipped with a sloping control panel houses the camera control unit. Cabinet contains the controls and pulser system necessary to operate an electro-optical shutter. Space is provided in this unit for an integrally mounted electronic precision counter. The light control unit is also contained in a standard relay rack cabinet. It includes all of the circuitry and controls for operation of the lighting system.

By combining optical, electronic and mechanical principles, a new ultra speed camera takes on standard, 35 mm film, from 480 to 1,600,000 pictures per second permitting visual analysis of events heretofore too short-lived to be studied adequately. Events of 60 microseconds when recorded by this camera and projected at the standard projector rate of 16 frames per second would stretch to 1 minute so that time is actually magnified 100,000 times.

Benson-Lehner Corp., Santa Monica, Cal. states that use of their camera has already accounted for revision of some fundamental laws. For instance, cavitation bubbles were treated as spherical in shape for mathematical analysis.

Studies have shown these bubbles to have non-spherical shapes which are greatly influenced by nearby solid boundaries at the time of their collapse. This revision may affect large areas of hydrodynamics. Fig. 1 is the photographic results of a 30 caliber bullet fired at 6500 ft. per second into a solid plastic plate.

Behavior of many high speed mechanisms has never before been observed under operational conditions for lack of a suitable, practical tool, capable of completely "freezing" their motion. Visual analysis of these ultra fast events may permit improvements in the design of many important industrial components.

Fig. 2 shows the complete camera system consisting of four units: camera, camera control unit, light control unit and flash lamp.

CAMERA OPERATION

Fig. 3 is a drawing of the shutter and objective assembly. A Kerr cell shutter unit consists of two polaroid filters, one

impacts cause metals to flow like viscous liquids.

HOTOGRAPHY

ws Explosions In Slow Motion

on either side of a 1¼" diameter cell containing nitrobenzene and two nickel electrodes which generate a controlled electric field. The plane of polarization of each filter is placed 90° in relation to one another, so no light passes through them while the electric field is off. Upon application of a high energy electric pulse, the nitrobenzene in the Kerr cell causes an additional 90 degrees rotation in the polarization vector, allowing light to pass through the second polaroid filter. For the required high speed rates, a very short pulse of 18,000 volts and 20 amps is used to control the electric field.

After the light rays pass through the shutter, two optical lenses transmit the image to a rotating mirror in the film box. The 35mm film lies, with emulsion side inwards, at the periphery of the circular film box, shown in Fig. 4. The rotating mirror is nickel plated aluminum, shaped like a wedge and attached to the shaft of a 100,000 rpm variable speed, compressed air turbine. Mounted at the center of the circle, with its face making an angle of 45 degrees to the axis of rotation, the mirror directs the light rays to the stationary film and, as it revolves, carries the image along the circular periphery of the film box.

The pulser and lighting systems described in Fig. 5, are linked together by delay, duration and triggering circuits, which provide the desired synchonization between shutter and lighting operations. An electronic counter unit permits accurate monitoring of exposure time, triggering delay and framing rate, by means of a six-decade crystal controlled oscillator with in-line numerical display (Nixie tubes). The special pulser system allows effective exposure times of .05 to 1.0 microseconds.

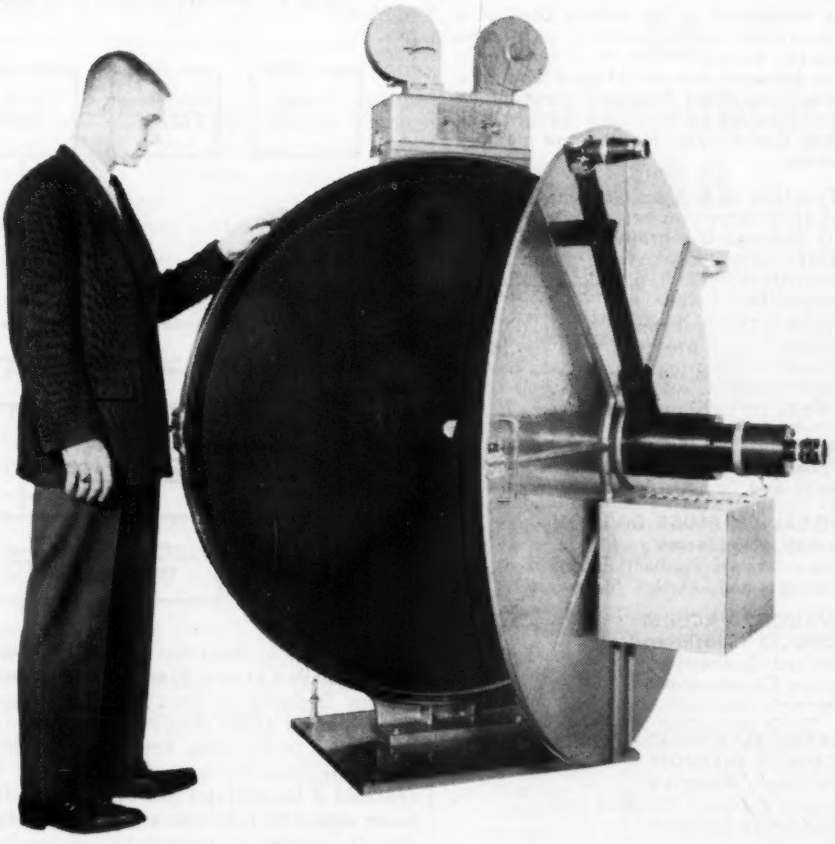


Fig. 4 The film lies with emulsion side inwards at the periphery of the circular shaped film box. Film magazine has a capacity of 400 feet. Film advance is push-button controlled, allowing automatic replenishment of the main camera chamber without set-up changes. Take-up and feed magazines are separate, permitting individual tests to be processed without reloading or rethreading the camera. Minimum total writing time is 0.0006 seconds for 240, 35mm frames, maximum is 0.5 seconds (dependent on mirror speed).

See next page for additional figures

Absence of complicated multiple mirror and prism mechanisms should assure consistently good photographic results throughout the life of the unit. Maintenance should be minimum in the electronic system, due to combination of conservative parameters and straight-forward, well-tried circuits. The only high speed mechanical component, the turbine-mirror assembly, represents a rugged, simple arrangement, capable of long and trouble free operation.

Circle No. 105 on Inquiry Card

a new symbol of magnetic progress

INDIANA

GENERAL

CORPORATION

This trademark is the calling card of a new science age company — Indiana General Corporation. It is born of a union between two established leaders — The Indiana Steel Products Company in permanent magnets . . . the General Ceramics Company in ferrites and memory systems.

Together, as Indiana General Corporation, they serve you better by placing at your disposal the brains and resources of two scientifically oriented concerns, both with records of significant achievement in their fields.

Indiana General can help you "design-engineer" your products with the latest magnetic innovations. Or, if you have a design problem, we can help you solve it. Write us outlining your needs.

INDIANA STEEL PRODUCTS DIVISION
Valparaiso, Indiana
Metallic and Ceramic Permanent Magnets

GENERAL CERAMICS DIVISION
Keasbey, New Jersey
Ferrites, Memory Products, Technical Ceramics and Chemical Stoneware

ADVANCED VACUUM PRODUCTS (Subsidiary)
Stamford, Connecticut
Alumina Ceramic-to-metal Hermetic Terminals

STEARNS MAGNETIC PRODUCTS DIVISION
Milwaukee, Wisconsin
Magnetic Materials Handling and Separation Equipment

THE INDIANA STEEL PRODUCTS COMPANY OF CANADA LIMITED
Kitchener, Ontario
Permanent Magnets and Stainless Steel Castings

If your product involves magnets or ferrites, Indiana General can help you make it better.

INDIANA GENERAL
CORPORATION
Valparaiso, Indiana

CIRCLE NO. 41 ON INQUIRY CARD

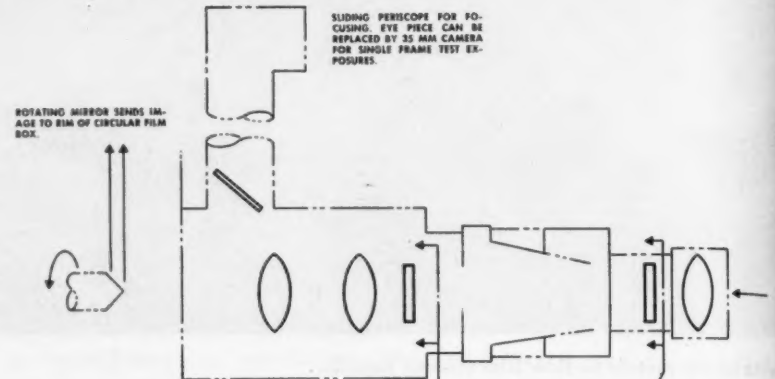

SLIDING PERISCOPE FOR FOCUSING. EYE PIECE CAN BE REPLACED BY 35 MM CAMERA FOR SINGLE FRAME TEST EXPOSURES.
ROTATING MIRROR SENDS IMAGE TO RIM OF CIRCULAR FILM BOX.
KERR CELL ADDS 90° ROTATION TO POLARIZATION VECTOR FOR SHUTTER ACTION.

Fig 3 Benson-Lehner Ellis Camera shutter and objective assembly.

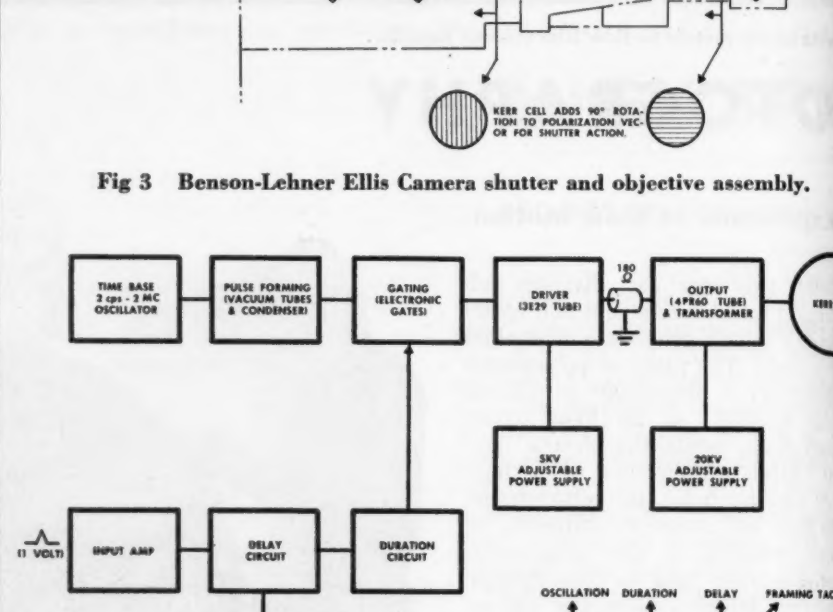


Fig. 5 Block diagram of the Benson-Lehner Ellis Camera System. The pulser system includes a time base oscillator generating a spike shaped wave with an amplitude of 25 volts. Frequency of this oscillator can be adjusted between 2 cps and 2 megacycles per second. Oscillator signal is fed into a pulse forming circuit composed essentially of modulator tubes and condensers. In this circuit, the negative component of the wave is removed, the amplitude is raised to 150 volts and the wave is integrated into a square pulse with .02 microseconds rise time. An electronic gating circuit releases the signal at the proper instant into a driver circuit consisting of a 3E29 vacuum tube with a plate potential of 4000 volts, and a 2-to-1 step down transformer, which feeds approximately 1500 into a 180 ohms impedance coaxial. An adjustable power supply with a 5 KV rating is provided to raise the driver tube's plate potential to the desired levels. The final output stage consists of a 4PR60 hard vacuum amplifier and an additional adjustable power supply with a 20 KV rating. The output stage feeds the Kerr cell field through a coupling co denser, to keep the 20 KV DC volta off the cell. Light transmission throu a Kerr cell is a non-linear function the applied voltage and minimum eff tive exposure time is slightly less th one half the rise time of the elect pulse. It is estimated that a minim effective exposure time of about 0.0 microseconds is possible with this sh ter. At maximum repetition rates, proximately 18,000 volts and 20 am are used to generate the Kerr cell fie Lighting is provided by a General El tric type FT 623 flash lamp. This la has a peak output rating of 4 x 1 lumens and an impedance of appro mately 2 ohms. Lighting energy is p vided by a square pulse of around 40 volts and two milliseconds durati The required 12,800 joules of ener are stored in a lumped parameter li consisting of 16 choke-capacitor el ments, each with 0.4 millihenry induc ance and 100 microfarads capacitan Normal light pulses reach more th 400,000,000 lumens at 3 millisecon duration. Higher outputs can achieved with shorter illumination tim

Power Supplies

32 page handbook, giving tabular specification data on more than 400 models, covers regulated d-c supplies, frequency changers (variable frequency power sources), high-voltage supplies (to 600 kilovolts), miniature transistorized inverters and converters and a-c line-voltage regulators. Included is extensive information on the selection and application of these units to achieve specific purposes.

Source: Sorensen & Co.
South Norwalk, Conn.
For your copy: Circle No. 240 on Inquiry Card

Mercury Thermostats

18 page catalog describes 3 standard merc thermostat groups; the well-type for sensing case temperature, the duct-type for gas or fluid temperature sensing, and the surface-type for area contact temperature sensing. Complete ready-to-mount package meets MIL-E-5272A.

Source: Vapor Heating Corp.
Vap-Air Division
Chicago, Illinois
For your copy: Circle No. 259 on Inquiry Card

Potentiometer Selector Chart

A precision potentiometer selector chart contains complete and easily read specifications including electrical, mechanical, mounting, special features and environmental information on 37 models of single and multi-turn precision pots. The chart, measuring 24″ x 30″, is suitable for wall mounting.

Source: Spectrol Electronics Corp.
San Gabriel, Cal.
For your copy: Circle No. 245 on Inquiry Card

Proximity Meter

28 page technical manual provides extensive information on a capacitance operated proximity meter. In textbook style, the manual covers basic capacitance, operating principles of the meter and complete descriptions of how the meter can be used for 15 types of measurements, such as concentricity and surface finish gauging, as a strain gauge, torque meter, pressure gauging and measurement of dielectric constant.

Source: Robertshaw-Fulton Controls Co.
Anaheim, Cal.
For your copy: Circle No. 242 on Inquiry Card

Miniature Relays

24 page catalog covering sub and micro miniature hermetically sealed relays includes a technical discussion on how to recognize and deal with dry circuits along with complete specs.

Source: Filtors, Inc.
Port Washington, N. Y.
For your copy: Circle No. 141 on Inquiry Card

Instrument Switches

28 page catalog discusses 3 structural types of switches. One type contains smaller terminals to accept a greater number of positions, each terminal clearly and permanently numbered directly on the terminal board itself. Catalog includes terminal board reference charts and complete engineering data.

Source: Cinema Engineering
Burbank, Cal.
For your copy: Circle No. 226 on Inquiry Card

Electronic Instruments

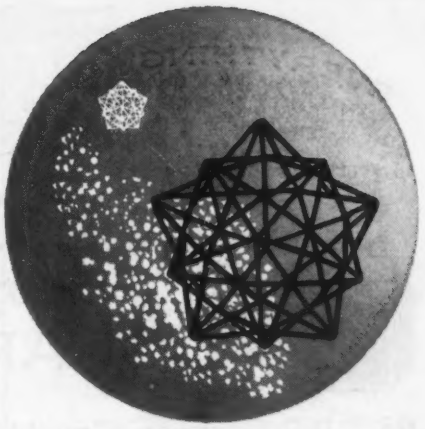
54 page catalog covers a complete electronic instrument line. Eight oscillators, covering a frequency range of 0.001 to 520,000 cps; six electronic variable band-pass and rejection filters, from 0.02 cps to 200,000 cps; nine power supplies, featuring ultra-high regulation, in ranges from 0-1 amps and 0-1200 volts dc; and three wide-range, low distortion amplifiers are shown. Helpful reference material, nomographs and tables for aid in measurements are included.

Source: Krohn-Hite Corporation
Cambridge, Mass.
For your copy: Circle No. 243 on Inquiry Card.

Fasteners

The root of a screw thread should be larger, rounder and better controlled than it is on most industrial and aircraft fasteners today, says Standard Pressed Steel Co. in its 20 page treatment of the subject. The difference between a good and a bad thread root —perhaps only as little as 0.002 inch in radius—may literally waste half the design load or 99 percent of the fatigue life of an otherwise sound fastener. Yet most standards, by and large, are not very specific about the thread root, mainly because of undue concern over gage interference, the SPS booklet states. The pamphlet, believed to be the first ever devoted to the root problem, provides a thorough review of the problem, including: a listing of the basic criteria for a good thread root; a comparative analysis of three widely used thread forms, including data on relative performance in tension-fatigue and at temperature; a complete specification for a large, round root radius that has been introduced in the aircraft and missile field; a capsule history of the evolution of this critical design aspect of the thread; an informative preview, in effect, of some new large-radius-root screw thread standards that are expected in the near future.

Source: Standard Pressed Steel Co.
Jenkintown, Pa.
For your copy: Circle No. 156 on Inquiry Card.



ENGINEERS
SCIENTISTS

FUTURISM in contemporary R&D

Radical departures from traditional forms of scientific investigation are the keynote of Republic Aviation's forward-looking programs in space exploration and upper atmosphere flight. In an environment that regards with skepticism the seeming validity of conventional conclusions, engineers and scientists seek below-the-surface solutions of problems... bypassing the superficial.

Expanding the scope and depth of present programs is Republic's recently completed $14 million Research and Development Center. Extensive facilities here are an invitation to professional men to realize the future by solving today's most perplexing problems.

• • • • • • • • • • • • • • • • • •

SENIOR LEVEL OPENINGS EXIST IN THESE IMPORTANT AREAS:

Navigation & Guidance Systems / Radar Systems / Information Theory / Radio Astronomy / Solid State & Thermionic Devices / Microwave Circuitry & Components / Countermeasures / Digital Computer Development / Radome & Antenna Design / Receiver & Transmitter Design / Miniaturization-Transistorization / Radiation & Propagation (*RF, IR, UV*) / Telemetry-SSB Technique

Please forward resumes to:
Mr. George R. Hickman
Technical Employment Manager,
Department 31D

REPUBLIC AVIATION

Farmingdale
Long Island, New York

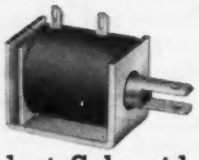
EVERYTHING UNDER CONTROL

with

SOLENOIDS

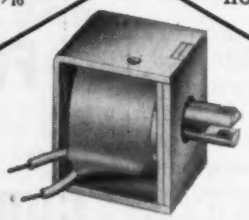
by

GUARDIAN®



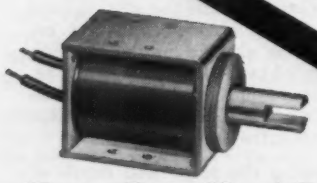
No. 22 D.C. Guardian's "mighty midget". Only ¾" x ¾" x 1⅛" size. Stroke ranges from 1/32" to 5/16" and lifts up to 24 ounces. Available D.C. voltage only for intermittent or continuous duty.

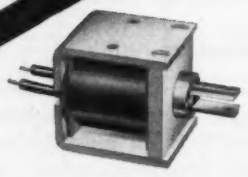
No. 24 A.C. Midget Solenoid. Only 1¼" x 1" x ⅞". Stroke ranges from 1/16" to ⅝" with lift over 19 ounces. Available for intermittent or continuous duty in any A.C. voltage up to 230 V.A.C.



No. 28 A.C. or D.C. MIDGET SOLENOID.

Announcement of this new Guardian midget solenoid will be greeted with eager interest by design engineers. It is most versatile. Has tapered plug and plunger for greater power. Adjustable stroke 1/16" to ½". Lift of over 41 ounces. Only 1⅛" x 1" x 1 3/16". Available A.C. or D.C.; intermittent or continuous duty.



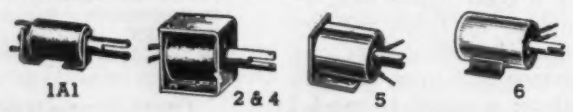


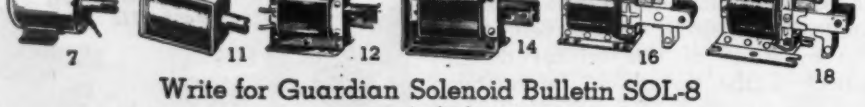
Heavy Duty No. 4 D.C. A version of Guardian's No. 4 solenoid. Has added power lift up to 9 pounds achieved by use of tapered plug and plunger, and special frame. Adjustable stroke ⅛" to ¾". Available for continuous or intermittent duty with D.C. voltages up to 110 V. D.C.

Heavy Duty No. 2 A.C. or D.C. A new version of Guardian's well-known standard No. 2 solenoid having greater power and much longer life expectancy well in excess of 15 million operations. Adjustable stroke 1/32" to ¾". Lifts more than 95 ounces. Available for A.C. or D.C.; intermittent or continuous duty.

Guardian offers the most complete, flexible and versatile line of solenoids ranging from midgets to heavy duty laminated types and for intermittent or continuous duty. Available with "Permaseal" encapulated coils and in D.C. units for 400 cycle operation.

LARGE SELECTIONS of Guardian Solenoids are carried in stock by Franchised Electronic Parts Distributors in the U. S. and Canada. Write for name of nearby distributor and Bulletin SD-25.





Write for Guardian Solenoid Bulletin SOL-8

GUARDIAN ELECTRIC

MANUFACTURING COMPANY

1562-D W CARROLL AVENUE, CHICAGO 7 ILLINOIS

CIRCLE NO. 43 ON INQUIRY CARD

WORTH FILING

Magnetic Tape Recorder

The third generation in a series of instrumentation magnetic tape recorders is covered in a 20-page booklet. An unusual amount of information on the high-performance, general-purpose recorder/reproducer is included. Performance figures for direct FM, pulse duration modulation and digital recording are included. Accessories which suit the modular machine to many individual requirements are described. A number of on-the-job applications are shown.

Source: Ampex Corp.
Redwood City, California

For your copy: Circle No. 246 on Inquiry Card

Electronic Instruments

Specifications and performance data are given in a 32-page catalog on a line of instruments for electronic, biological and chemical measurement and control. Electrometers and micro-microammeters are among the instruments covered.

Source: Keithley Instruments, Inc.
Cleveland, Ohio

For your copy: Circle No. 215 on Inquiry Card

WORTH BUYING

Electromechanical Switches

All you need to know about design selection and application of electromechanical switches are in this 24-page reprint of Components Digest 8, Parts I and II. Supply is limited. Fifty cents per copy. Check or money order must accompany order.

Write to: Reprint Editor
ELECTROMECHANICAL DESIGN
1357 Washington St.
W. Newton, 65, Mass.

Precision Spring Design

16 pages detailing the complete design procedure for precision compression and extension springs. 2 sample problems, 1 for precision compression and 1 for precision springs, worked out in detail on typical design procedure work sheets. 9 tables, 13 graphs, 4 nomographs, 4 detailed drawings, 2 worksheets.

Price: 50 cents each — 3 for $1.00 — 8 for $2.00. Check or money order must accompany request.

Order from: Reprint Editor
ELECTROMECHANICAL DESIGN
1357 Washington St.
W. Newton 65, Mass.

WORTH FILING

Wire Mesh Heating Element

16 page catalog details reliability features of wire mesh type heating elements, listing data on its versatility, physical properties and thermal characteristics. Units are adaptable to fit the most complicated hard-to-fit surfaces.

Source: Electrofilm, Inc.
No. Hollywood, Cal.

For your copy: Circle No. 229 on Inquiry Card

Relays

24 page booklet covers medium size and miniature telephone type relays with a great range of contact combinations including bifuricated, heavy duty and power contacts. Also covered are hermetically-sealed and microminiature crystal can relays that meet current Mil specs.

Source: Magnecraft Electric Co.
Chicago, Illinois

For your copy: Circle No. 160 on Inquiry Card

Instrument Meters

For all those who recommend, specify and buy instruments of laboratory standard quality, a 24-page brochure details and diagrams each major component, including construction and choice of special materials. Instruments described include d-c voltmeters and ammeters; a-c or a-c and d-c voltmeters, ammeters, and wattmeters; current transformers; and low and high voltage potential transformers. A supplementary data section on transformer ratio and phase angle curves indicates necessary corrections for residual errors that instrument transformers may induce in a measuring system.

Source: Weston Instruments Div.
Daystrom, Inc.
Newark, N. J.

For your copy: Circle No. 227 on Inquiry Card

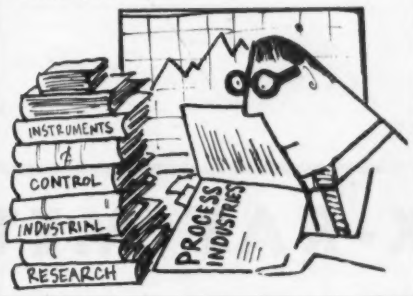
Package Circuitry

Newly revised quick order guide helps design engineers plan and package circuitry. The 20-page booklet lists off-the-shelf components used in making up complete electronic systems Also offered is a new brochure which graphically describes a method of modular construction of electronic units from off-the-shelf components

Source: Alden Products Co.
Brockton, Mass.

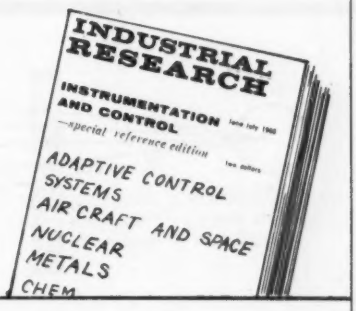
For your copy: Circle No. 228 on Inquiry Card

The nation's leading instrumentation authorities are busy writing a special Reference Book *on all that's new in instrumentation & control for . . . . . the man who uses instrumentation & control devices (how the major industries can; will, and* should *profit from them).*



. . . the producer of instrumentation & control devices (what industry wants from him—and how he can answer its problems).

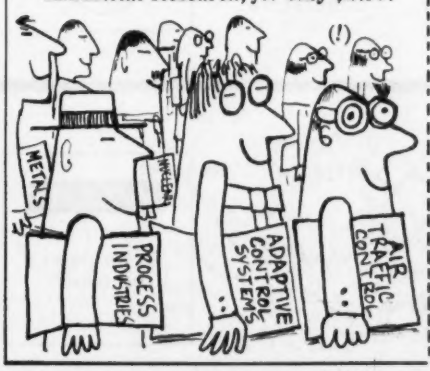
This thick, $2 reference volume will be published as the June-July issue of Industrial Research *magazine. It's a* must *for everyone interested in this fast-moving field.*



That's why 51,000 engineers and technical executives have put in their orders ahead of time.

Some requested the reference edition of I•R only.

But most *of them took advantage of a special offer and got the $2 edition, plus a $5, one-year subscription to* Industrial Research, *for* only *$2.50.*



Why don't you?

☐ **Reference edition** **$2**

☐ **Reference edition, plus one year of Industrial Research** **$2.50**

Name: _____

Title: _____

Company: _____

Address: _____
street

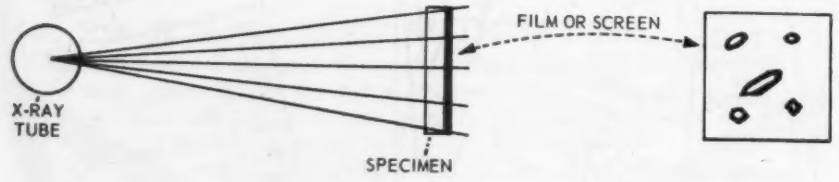
_____
city zone state

INDUSTRIAL RESEARCH
200 S. Michigan Av., Chicago 4, Ill.

Instrument advertisers: *an additional 20,000 circulation (51,000 total) is offered in this one issue, at no increase in rates.*

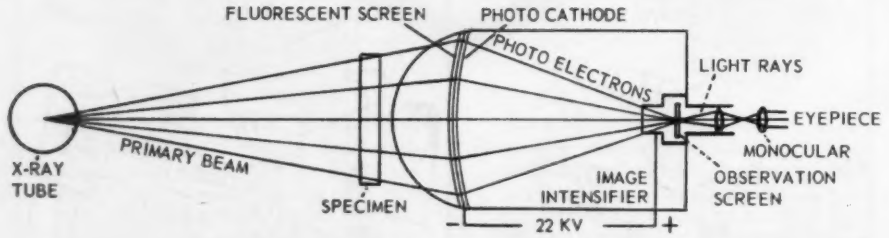
The different types and applications of x-ray methods can become confusing to the design engineer who only has occasional use for these techniques. These 10 simplified diagrams and explanatory notes may help solve some problems —now or in the future. The information for these charts was supplied by Philips Electronic Instruments of Mt. Vernon, N. Y. For a free wall-chart of these techniques:
Circle No. 113 on Inquiry Card

X-RAY METHODS



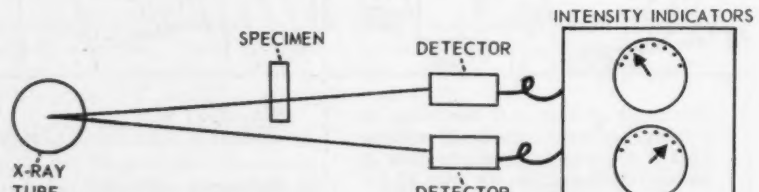
Industrial Radiography and Fluoroscopy

Equipment checks internal physical structure of many materials. Spots on film indicate voids or other density variations. High voltage X-Ray units produce hard radiation needed to penetrate thick specimens.



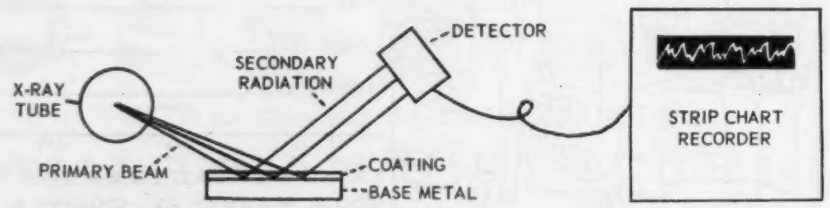
Industrial Fluoroscopy With Image Intensifier

Used for inspection of steel welds, heavy rubber sections, honeycomb, thick plastic parts, ordnance materials, homogeneity of fuel elements.



X-Ray Absorption

Instrument compares direct intensity from X-Ray tube with that remaining after passing through specimen. The ratio of the two readings determines chemical composition by applying laws of X-Ray absorption.

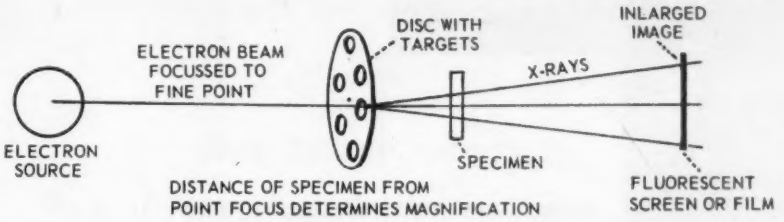


X-Ray Fluorescence Absorption

Instruments used for measuring tin coating on steel plate and other similar applications. Primary beam causes base metal to fluoresce. Secondary rays are partially absorbed by coating. Detected intensity remaining is a measure of coating thickness.

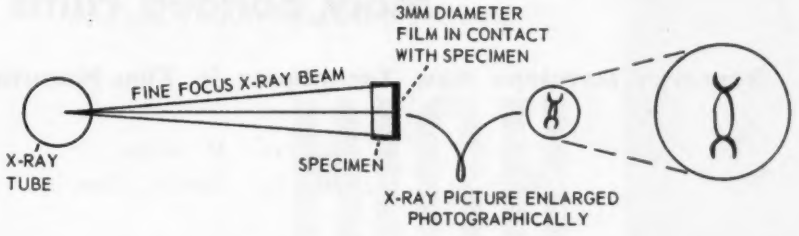
Projection Microradiography (X-Ray Microscopy)

For critical evaluation of opaque specimens. Choice of different targets during operation, stereo micrography, absorption analysis handled on this instrument. An adjunct to light and electron microscopy.



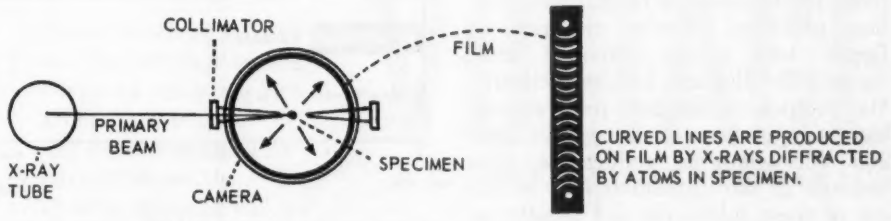
Contact Microradiography

For examining opaque minute specimens for microscopic detail. Small table unit employs 5kv or less to produce soft X-Rays needed for work on thin biological and foil specimens.



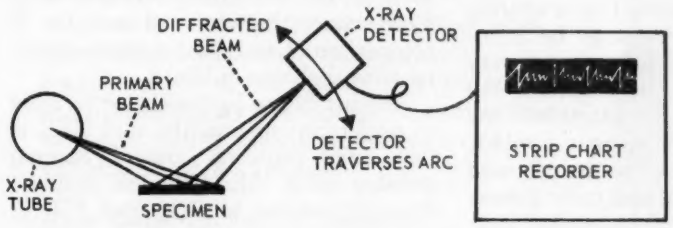
X-Ray Diffraction

Analyzes for all compounds such as NaCl (sodium chloride). Each substance produces a different X-Ray "fingerprint"



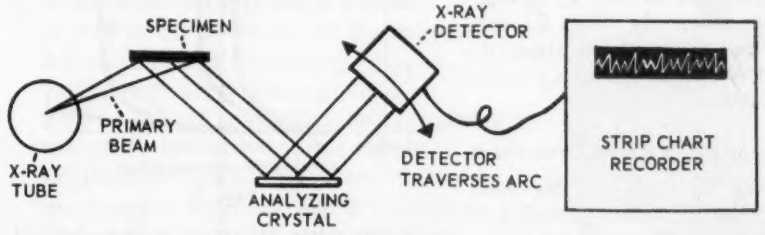
X-Ray Diffractometry

Analyzes for all compounds such as NaCl (Sodium Chloride). Same principle as diffraction except film replaced with detector and chart to give faster, more accurate data. Eliminates film processing and measurement.



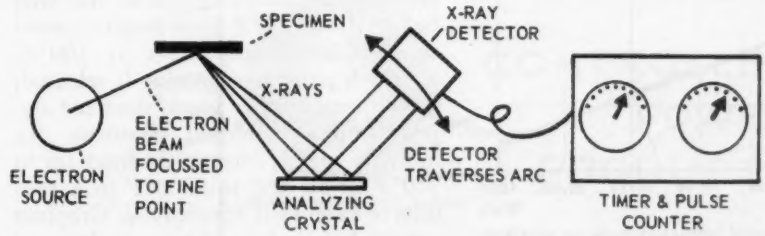
X-Ray Spectrography (Fluorescence)

Analyzes for elements in atomic range from #12 (magnesium) to #98 (Californium). Automatic X-Ray spectrograph is available for production line control with strip chart replaced with printout console. Results are printed on tape for as many as 24 elements as fast as samples are inserted.



Electron Microbeam Probe

For qualitative and quantitative analysis of specimen surface in one cubic micron area. Used with optical microscope for studying varying composition in localized regions. Specimen acts as target and gives off X-Rays from spot. Electromechanical devices provide motion for scanning the specimen. Detector need not move in arc if curved crystal is used.



Moly Bonded Films

Research Develops New Techniques in Film Manufacture and Application

by Peter M. Magie,
Bemol, Inc., Boston, Mass.

Since their origination in 1948, bonded solid lubricants have been applied to the solution of many lubrication problems. Recent research by Bemol into factors affecting moly bonded film life and friction—primarily film composition, surface pretreatment, high temperature characteristics, and film thickness—has reduced a large measure of the unpredictability in the use of these lubricants and greatly extended their applications.

A bonded solid lubricant is a colloidal dispersion of a solid lubricant in a resin binder applied as a coating on the rubbing surfaces to be lubricated. The resultant film possesses very low frictional values and extreme endurance. Figure 1 demonstrates the endurance of a molybdenum disulfide (moly) bonded film compared with that of moly powder and moly grease, which are already well-known for their extreme endurance as lubricants.

Performance of bonded films depends upon four principal factors: 1) characteristics inherent in the film, 2) mechanical factors of the application, 3) pretreatment of surfaces, and 4) method of application.

PROPERTIES INHERENT IN THE FILM

Bemol's choice of moly as the solid lubricant in the film has rested primarily on its low frictional values compared to graphite or TFE (tetrafluoroethlene). Testing kinetic coefficients of friction has shown moly films to average .01 while graphite and TFE films average between .03 and .08. A comparison of moly and graphite bonded films is shown in Fig. 2.

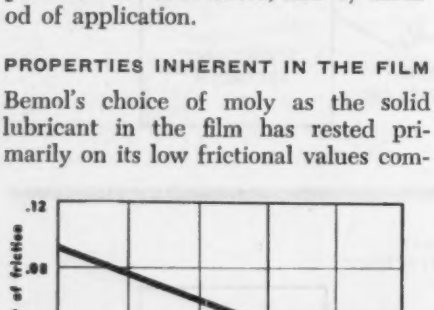


Fig. 2

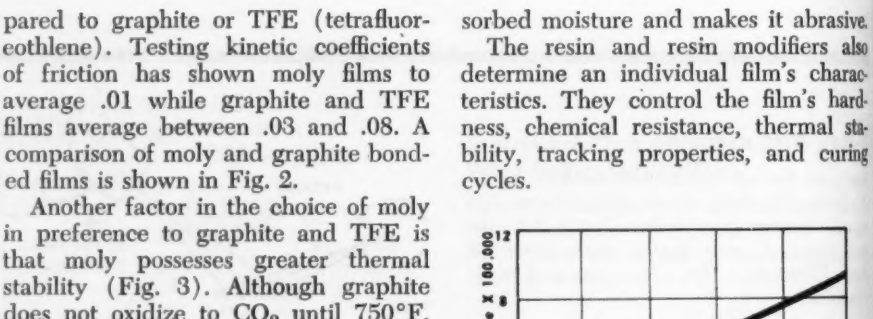


Fig. 1

Another factor in the choice of moly in preference to graphite and TFE is that moly possesses greater thermal stability (Fig. 3). Although graphite does not oxidize to CO_2 until 750°F, graphite's low frictional values depend on absorbed moisture. Because heat drives off the adsorbed moisture in graphite, abrasivity begins to rise well below 750°F. TFE films begin to show appreciable decomposition at 400°F, at which point free fluorine is released. Moly, on the other hand, does not depend upon absorbed moisture for lubricity and is chemically inert up to 750°F in air and to 2300°F in a vacuum or in an inert atmosphere. Graphite cannot be used in a vacuum because low vapor pressure draws off its adsorbed moisture and makes it abrasive.

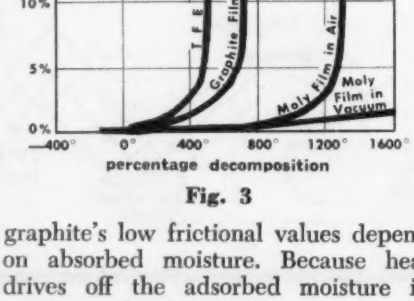


Fig. 3

The resin and resin modifiers also determine an individual film's characteristics. They control the film's hardness, chemical resistance, thermal stability, tracking properties, and curing cycles.

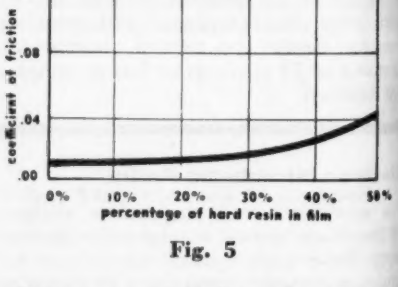


Fig. 4

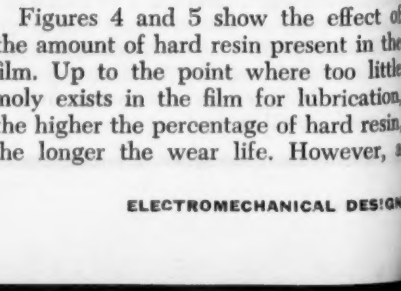


Fig. 5

Figures 4 and 5 show the effect of the amount of hard resin present in the film. Up to the point where too little moly exists in the film for lubrication, the higher the percentage of hard resin, the longer the wear life. However, a

higher percentage of hard resin tends to increase the frictional coefficients of the film. Therefore, the resin to moly ratio must be determined with a view to the primary function of the film. For example, guidance control gearing requires the low frictional properties of a film with a high moly content, whereas industrial open gears require the long life properties of a film with a high resin content.

MECHANICAL FACTORS AFFECTING FILM LIFE AND FRICTION

Figure 6 demonstrates that bonded film life decreases as speed increases under conditions of high loading. This occurs because high speeds and high

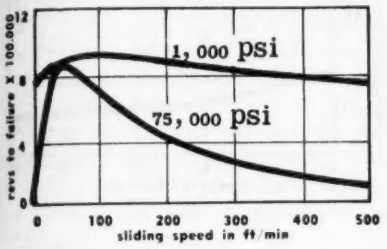


Fig. 6

loads generate high contact heat which tends to decompose the resin binder. However, if the applied load is small at high sliding speeds, such as on computer parts, film life can be expected to be permanent. Conversely, in wire drawing, loads can exceed 300,000 psi at high sliding speeds, and film life can be expected to be short. Figure 7 shows friction to be virtually constant, regardless of speed.

The importance of load on film life is also demonstrated in Fig. 8, which shows that under constant speed (50 ft/min) at room temperature life decreases under increasing loads. In contrast to graphite or TFE films, moly films show decreasing frictional values as load increases (see Fig. 9). This is due to the compressive alignment of lamellar moly particles.

Temperature also plays a part in bonded film life and friction. Extreme high heat softens the film and decreases film life (see Fig. 10). Frictional values, however, remain almost constant until temperatures rise above 750F, at which point moly begins its slow oxidation in air (see Fig. 11). In the absence of an oxidizing atmosphere

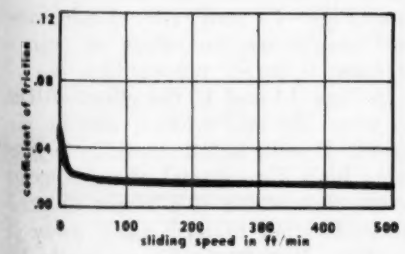
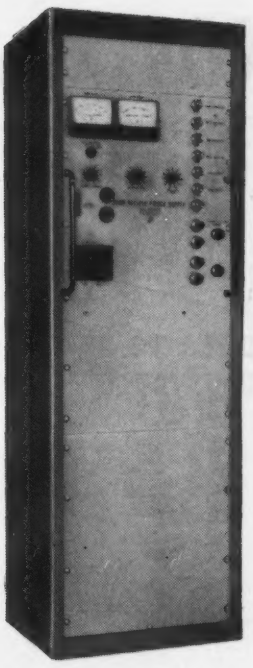


Fig. 7

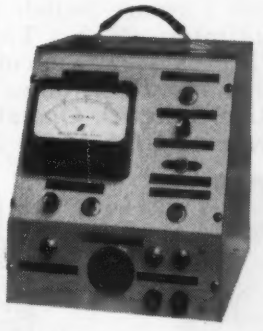
Safe. Easy to operate.
Rate of voltage application conforms to ASTM standards. Portable models. Floor mounted models.



HIGH VOLTAGE

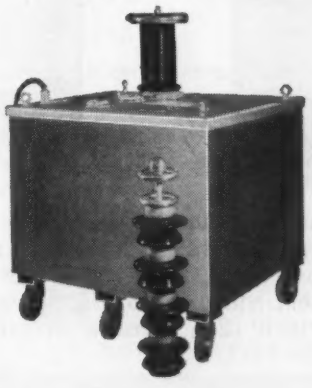
A-C AND A-C/D-C TESTERS

These Sorensen a-c and a-c/d-c testers completely cover the voltage range from 0-150,000 vac and 0-300,000 vdc with current capacities as high as 4000 milliamperes a-c (plus 5 milliamperes d-c for the a-c/d-c units).



All components are conservatively rated to insure maximum life and top performance. Maximum rated current can be drawn continuously over the entire output range and overloads may be supplied for a short time to "burn" faults. Easily reversible d-c polarity of a-c/d-c testers.

New Catalog. Just off the press, Sorensen's new 32-page catalog gives technical data on the complete line of Sorensen a-c and a-c/d-c testers as well as on Sorensen h-v d-c supplies, h-v electrostatic generators, low-voltage d-c power supplies, a-c line-voltage regulators, and frequency changers. Extensive power supply application data is also given. Write for your copy today. Sorensen & Company, Richards Ave., South Norwalk, Conn.



0.4

Sorensen
A SUBSIDIARY OF RAYTHEON COMPANY

CONTROLLED POWER PRODUCTS

...the widest line lets you make the wisest choice

CIRCLE NO. 45 ON INQUIRY CARD

NOW MINIATURE & SUBMINIATURE

HAYDON PRESSURE SWITCHES

ADDED TO STANDARD 1500 SERIES ADJUSTABLE PRESSURE SWITCH LINE ▶▶▶

(6 ounces, 3⅞" x 1⅝")

1580 & 1880

The 1580 *Miniature Gage* Pressure Switch (4 ounces maximum, 3" x 1½") and the 1880 *Miniature Absolute* Pressure Switch (4 ounces maximum, 3¼" x 1½") have SPDT or DPDT circuitry, with either sealed or unsealed snap-action switches. Operating pressure range: 0.5 psi to 3,000 psi.

1590

1890

The 1590 *Subminiature Gage* Pressure Switch (2½ ounces maximum, 3" x 0.937") and the 1890 *Subminiature Absolute* Pressure Switch (2½ ounces maximum, 2¼" x 0.875") have SPDT circuitry with sealed or unsealed snap-action switches. Operating pressure range: 10 psi to 3,000 psi.

GENERAL DESIGN SPECIFICATIONS APPLICABLE TO ONE OR MORE OF THE ABOVE VERSIONS.

Sensing elements: A wide variety of diaphragm or piston sensing elements can be provided in each of the configurations. Thus, a standard design is easily tailored to specific pressure settings and environmental conditions. Pressure switches are available with welded metal sensing elements when corrosive media or extreme temperatures dictate all metal construction.

Operating media: Ammonia systems, freon, lubricating and hydraulic oils, aircraft fuels, radioactive water, oxidizers.

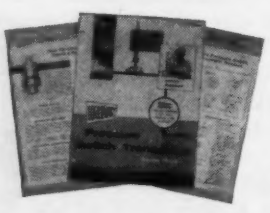
Environmental: Switches meet applicable portions of MIL-E-5272, high and low temperature, shock and vibration:

Standard temperatures:
−65° to 250°F.
Vibration: 10g.
Special designs made to 600°F. and vibration to 20g.

Electrical: Snap-action switches meet MIL-S-6743. 5 amp. res./3 amp. ind. at 30v DC/125v AC.

Higher electrical loads available: 10 amp. res./8 amp. ind.

Write today for your copies of HAYDON PRESSURE SWITCH BULLETINS: 1500-1, 1580-1, and 1590-1.



HAYDON Switch INCORPORATED
WATERBURY 20, CONNECTICUT

CIRCLE NO. 46 ON INQUIRY CARD

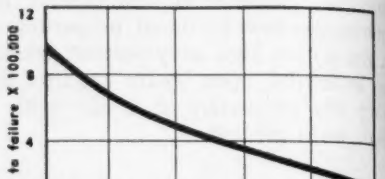


Fig. 8

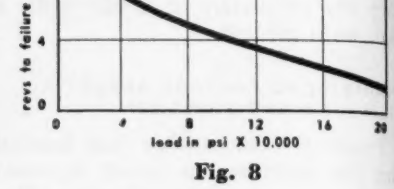


Fig. 9

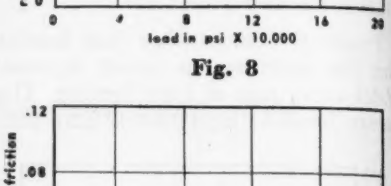


Fig. 10

Fig. 11

moly bonded films have been used at temperatures up to 2300F without significant frictional increases.

The degree of surface hardness is another factor governing bonded film life and friction. Because the film depends upon the elasticity of the surface to which it is bonded, harder metals provide a non-buckling surface for a continuous, low frictional film (see Figs. 12 and 13). Under low load conditions the effect of surface hardness is barely perceptible.

In Figs. 14 and 15 the effect of time on wear life and friction can be observed. During initial break-in, a relatively high dimensional change occurs in the film which is a result of compression rather than shearing away of the film. Running-in at gradually increasing loads can increase film life

by as much as 200% when compared to shock impact loading. After break-in, film wear occurs at a very slow, constant rate. Figure 15 shows that a film's low frictional values remain constant through time.

EFFECT OF SURFACE PRETREATMENT

The nature of pretreatment given to the surface is very important to long film life. Recommended procedure involves degreasing, sandblasting, and chemical pretreatment.

Figure 16 demonstrates the effect of surface finish on film life. Too smooth a surface does not permit good adhesion, while too rough a surface causes the applied load to be concentrated only on the peaks; and consequently, film life is shortened. Optimal film life can be expected when surface finish is in the 20-70 micro-inch (rms) range.

Following mechanical pretreatment comes chemical pretreatment, which serves to increase the adhesiveness of the bonded film to the surface. Figure

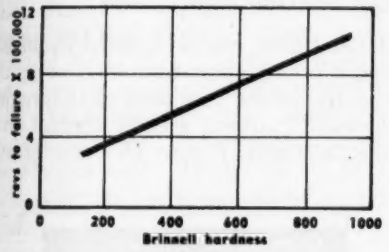


Fig. 12

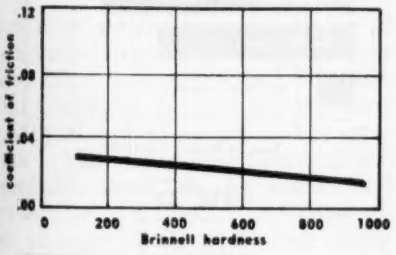


Fig. 13

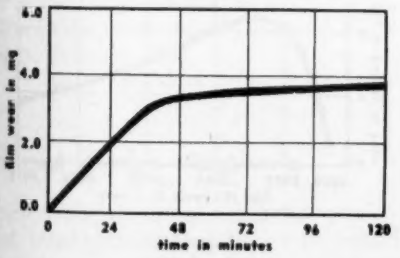


Fig. 14

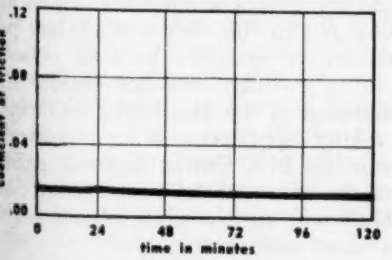
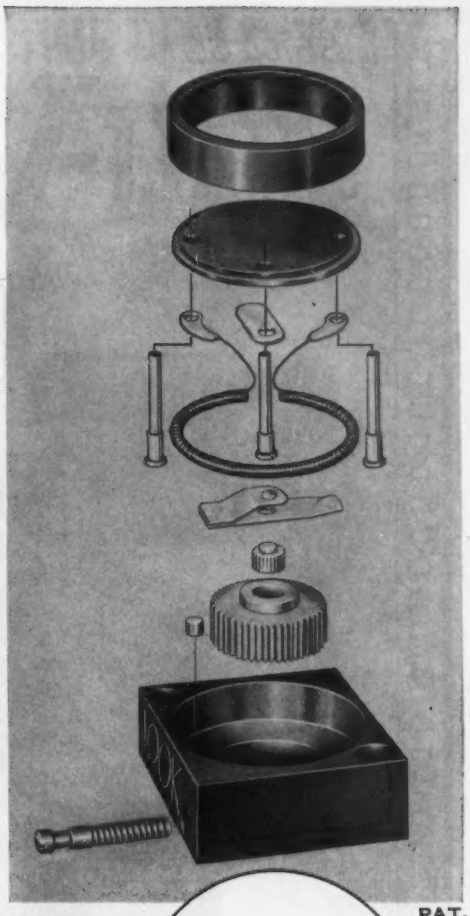


Fig. 15



PAT. PEND.

ACTUAL SIZE

NEW! TAKE A LOOK AT THE GUTS OF HANDLEY'S WEETRIM POT

...the Precision Trimming Potentiometer that will Standardize the Industry The Handley WeeTrim trimming potentiometer will standardize the type...and, as with other Wee Line products, WeeTrim is manufactured under strict quality control. Lightweight, wee in size, extremely stable, and WeeTrim has the other exclusive Handley Wee Line features. Write today! Literature will be provided immediately.

HANDLEY, INC.

12960 PANAMA STREET, LOS ANGELES 66, CALIFORNIA

HANDLEY REPRESENTATIVES

ARIZONA
E. J. Foley & Associates
3840 N. Jokake Dr., Scottsdale

CALIFORNIA
E. L. Berman Company
450 9th St., San Francisco

COLORADO
Howell Sales, Inc.
4637 Dudley, Arvada

FLORIDA
Specialized Equipment Co.
Box No. 323, Cocoa Beach

ILLINOIS
Ellinger Sales Corp.
6540 N.W. Hwy., Chicago 31

MASSACHUSETTS
Electronic Components & Services
Box No. 35, Newton Centre

MICHIGAN
Willis L. Trombley & Son
3035 E. Grand Blvd., Detroit 2

MISSOURI
Leemark Associates
Box No. 8467, Kansas City

NEW JERSEY
John W. Richardt Co.
Route No. 46
Pine Brook

NEW YORK
Leo Jacobson Co., Inc.
1366 Kenmore Avenue
Buffalo 23

OHIO
C. A. Robinson Company
4143 Mayfield Road
Cleveland 21

PENNSYLVANIA
Samuel A. Jeffries, Inc.
105 Forrest Avenue
Narberth

TEXAS
Koch Engineering & Sales
309 Meadows Building
Dallas 6

WASHINGTON
Howell Sales, Inc.
2029 McGilvra Blvd.
Seattle 2

CIRCLE NO. 47 ON INQUIRY CARD

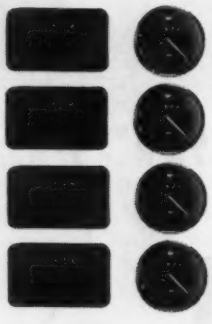
BH100 Series

MILLI-V-METER®

The instrument with the TAPE-SLIDEWIRE

for Test Cells
Ground Support
Flight Deck
Telemetry

...to accurately indicate



TEMPERATURE
R.P.M.
PRESSURE
FLOW

1/10 THE SIZE, 10 TIMES THE ACCURACY
(of standard instruments)!

These 3x5" and 3"-dia. instruments are used by many manufacturers and laboratories to measure every parameter... in missile, aircraft or ground support. Ideally small and matched for panel uniformity, they offer reading of the individual phenomenon or of many states through selector switching... with fast response. Every measurement exhibited on the counter is a definitely calibrated value. Component density of the 3"-dia. BH183 is the highest obtainable combined with ultimate instrument accuracy. Manufactured to MIL-E-5272 and MIL-I-6181 specs.

FEATURES:

1) •Accuracy 1 part in 1000.
2) Laboratory precision for the military or industry.
3) Compatibility with any transducer —AC or DC.
4) For strain gage, linear differential transformer, thermocouple, thermistor, resistance thermometer, pulse or variable frequency circuits or systems.
5) Available with re-transmitting slidewire.
6) Every scale unit a calibrated value.
7) Operates directly from 60- or 400-cycle power.

Produced by the makers of JETCAL® jet engine Analyzer... in worldwide military and airline use!

Full information is available for the asking!

B & H INSTRUMENT CO., INC.

3479 West Vickery Blvd., Fort Worth 7, Texas

Sales-Engineering Offices:
ATLANTA, GA., COMPTON, CAL., DAYTON, OHIO, VALLEY STREAM, L.I., N.Y., WICHITA, KAN.
TORONTO, ONT. *(George Kelk Ltd.)* MITCHAM, SURREY, ENGLAND *(Bryans Aeroquipment Ltd.)*

CIRCLE NO. 48 ON INQUIRY CARD

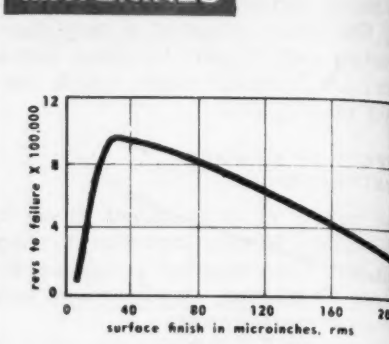


Fig. 16

17 shows the extreme importance of the chemical coating on film life. Pretreatment compounds vary greatly from metal to metal and include such compounds as iron manganese phosphates, oxalates, and chromates. Proper chemical pretreatment results in dimensional changes averaging less than .0001 inches.

APPLICATION PROCEDURE

Bonded films can be applied by brushing, dipping, spray-tumbling, or spraying. By far the best method is spraying because it allows greater control over film thickness. Figure 18 demonstrates

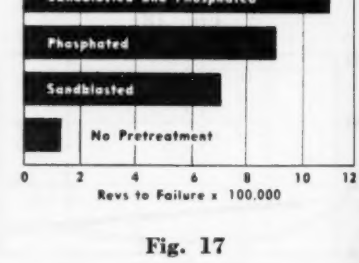


Fig. 17

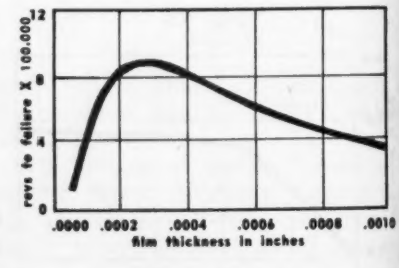


Fig. 18

the importance of film thickness on long life. A film that is too thick has poor endurance qualities because cohesion within the film becomes greater than adhesion of the film to the surface.

After application it is necessary to cure the film. Curing depends entirely on the nature of the binder resin. Some films will air-dry while others require a short heat cure.

Circle No. 107 on Inquiry Card

New Material For Hi Temp

"Asbestosite," a new refractory material is said to withstand continual exposure to temperatures in the 1000°F. to 3000°F. range and intermittent exposure at much higher temperatures. "Asbestosite" is easily fabricated in a wide variety of shapes and sizes and may soon be available in metalclad configurations. The strong, rugged material possesses the ability to withstand extreme thermal shock. Harco Laboratories, New Haven, Conn.

Circle No. 236 on Inquiry Card.

Hi-Temp Reinforced Plastic

Designated TRC-X phenolic laminate, a reinforced plastic was developed to meet the need for a low-dielectric, structurally strong material that consistently withstands higher temperatures (1000F range) and instantaneous thermal shock and yet retains good structural properties. TRC-X laminate is also used as a heat insulation barrier. When bonded to aluminum, for example, its low thermal conductivity prevents high skin friction temperatures from annealing the metal underbody. Consequently, the aluminum structure retains its strength. Riverside Plastics Corp., Hicksville, N. Y.

Circle No. 146 on Inquiry Card

Glass Base Epoxy Laminates

Two new general-purpose grades of epoxy-impregnated, glass base laminated plastics are designed for electrical insulation applications requiring high reliability in severe service conditions. They offer low electrical loss properties, good arc resistance, and excellent tensile, impact, and compressive strength. Both grades are designated as NEMA G-10 laminates and meet requirements for MIL-P-18177B, Type GEE. Continental-Diamond Fibre Corp., Newark, Del.

Circle No. 143 on Inquiry Card

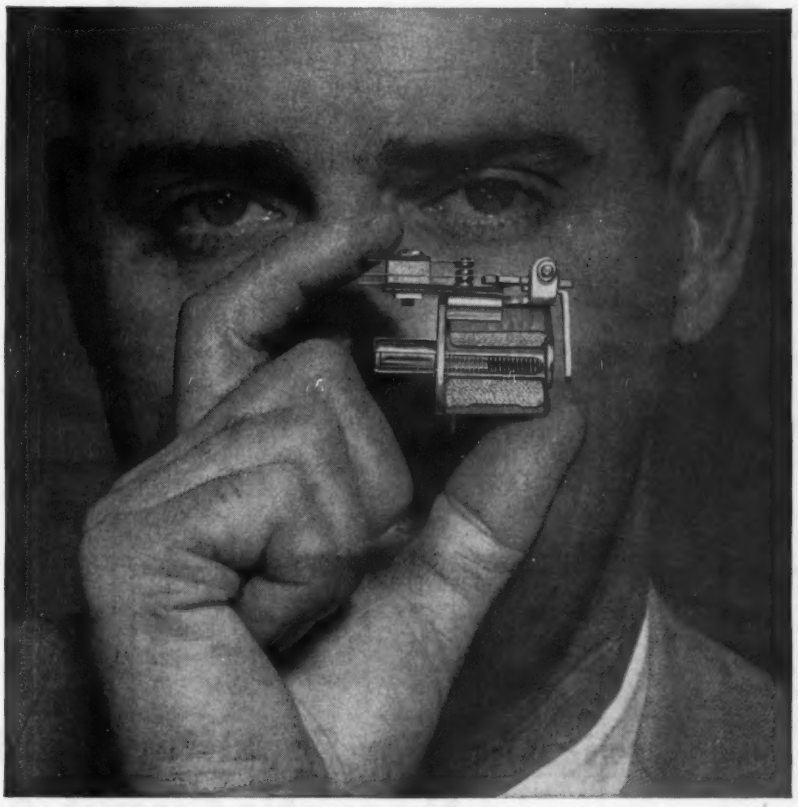
Printed Circuit Plugboards

Printed circuit designs can be quickly and inexpensively laid out and tested in prototype using plugboards of 1/16" thick epoxy paper material with 0.062" holes on alternate intersections of 0.1" grid. A 16-pin Elco Varicon Series 5001 connector is attached to the lead-edge mating with a Varicon Series 7001 16 contact receptacle. Plugboards, using push-in or stand-off terminals, may be hand wired to provide prototypes for final printed circuit cards. Vector Electronic Co., Glendale, Cal.

Circle No. 94 on Inquiry Card

COMPACT, 3-OUNCE TIME DELAY RELAY

with silicone-controlled delay from 1/4 to 120 seconds



Worth a closer look . . . the Heinemann Type A Silic-O-Netic Relay. Despite its small overall size, the relay offers many big performance features.

For example, double-pole, double-throw switching . . . at fast snap-action contact speed.

The relay is a load carrier in itself: it may be energized continuously . . . does not require auxiliary lock-in circuits.

And it has a hermetically sealed time element that is forever free from the effects of aging or fatigue. The Type A Relay has proven itself in countless applications; it will give you reliable service over a long, long operational life.

For full details, refer to Bulletin T-5002. A copy will be sent on request.

BRIEF SPECS

Time Delays: from 1/4 to 120 seconds

Overall Dimensions: 2-1/16" x 2" x 1-9/16"

Contact Capacity: 3 amps at 120V AC, 1.5 amps at 240V AC (non-inductive load), 1 amp at 50V DC, 0.5 amp at 125V DC.

HEINEMANN

ELECTRIC COMPANY

125 Plum St., Trenton 2, N. J.

S.A. 1079

CIRCLE NO. 49 ON INQUIRY CARD

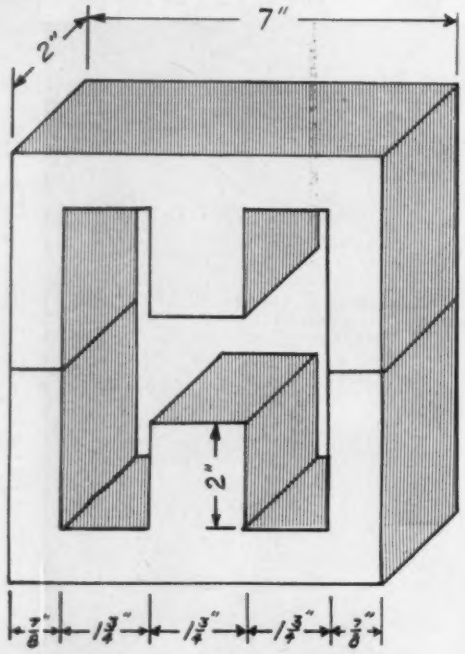


Fig. 1 Modified E-19 laminations (Joined as shown).

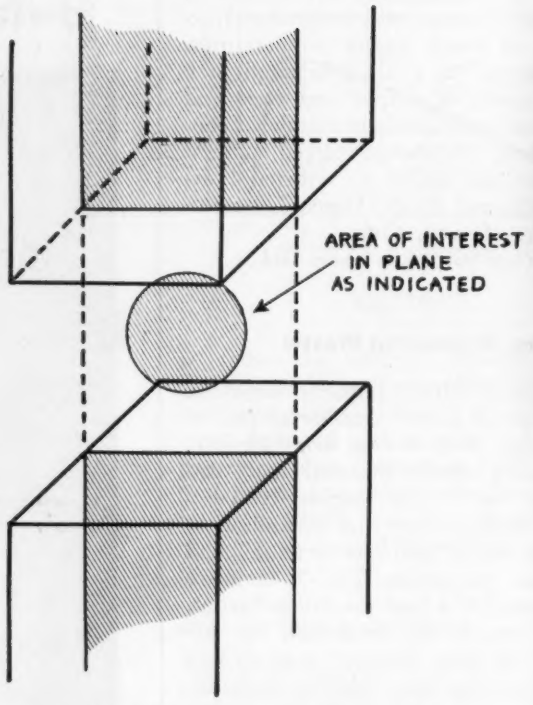


Fig. 2 Specified area of uniform field intensity.

Designing for Specified Field Distribution in Magnetic Circuit Air Gaps

By Rodney E. Post and J. Zdzieborski
The Hays Corporation
Michigan City, Indiana

Techniques recently developed in obtaining a highly uniform field density in a given area of an electromagnet air gap appear to offer a simplified approach to other air gap field density problems.

The electromagnet investigated consisted of two, two-inch stacks of standard EI-19, E-laminations, modified and assembled as shown in Fig. 1.

The problem was to obtain a uniform field density within a one inch diameter circle in the center plane of the air gap as illustrated in Fig. 2.

The electromagnet coils were placed around the center leg of each lamination stack and connected series aiding. Field density data was taken at various points in the air gap with the flat pole faces, as shown in Fig. 3. This data tabulated in Fig. 4 illustrates the non-uniformity of the field obtained.

The field density variations within the area of concern were ±16%, whereas the design goal was uniformity within ±1% or better. As the data illustrates, non-uniformity, caused by fringing of the field at the pole face edges, consisted of a high field density in the center with decreasing field density toward the outside.

In the ideal magnetic circuit, there is no fringing effect and changes in air gap do not shift the operating point of the iron; thus field density at any point in the air gap varies inversely with changes in the length of air gap. The basic assumption used in development of the design equations was that this law for the ideal circuit holds for small air-gap changes in the actual circuit.

This assumption was used solely as a basis for establishing uniform field density within the given area. It could not be used to predict the absolute value of field strength. Once a uniform field is established the desired field strength can be obtained by application of the model theory described in "Magnetic Circuits and Transformers", by Members of the Staff of the Department of Electrical Engineering, Massachusetts Institute of Technology (John Wiley and Sons, Inc.).

DESIGN CALCULATIONS

Review of the data in Fig. 4 revealed that flux density varies along the vertical centerline. The value of flux density on this centerline at the pole face was chosen as the reference (or 100%) point (B_{ref}). This was the point of highest flux density and greatest stability (least influenced by fringing).

Data in Fig. 4 gives flux density values for the points shown. These values were expressed as a percentage of the reference value (B_{ref}). The difference ($1-B_o/B_{ref}$) L was denoted h_o, where L is one half the air gap length (see Fig. 5).

The flux density (B_o) at the center of the circle of constant flux density was 86.04% of the established reference at the pole face, or 13.96% below the 100% value. This means that, in accordance with the previously stated

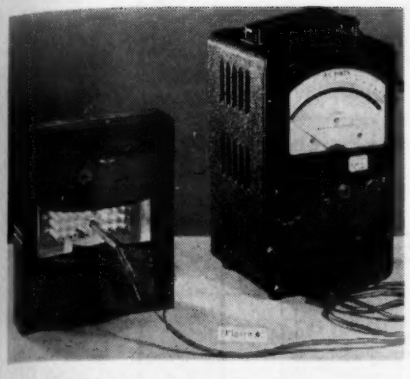
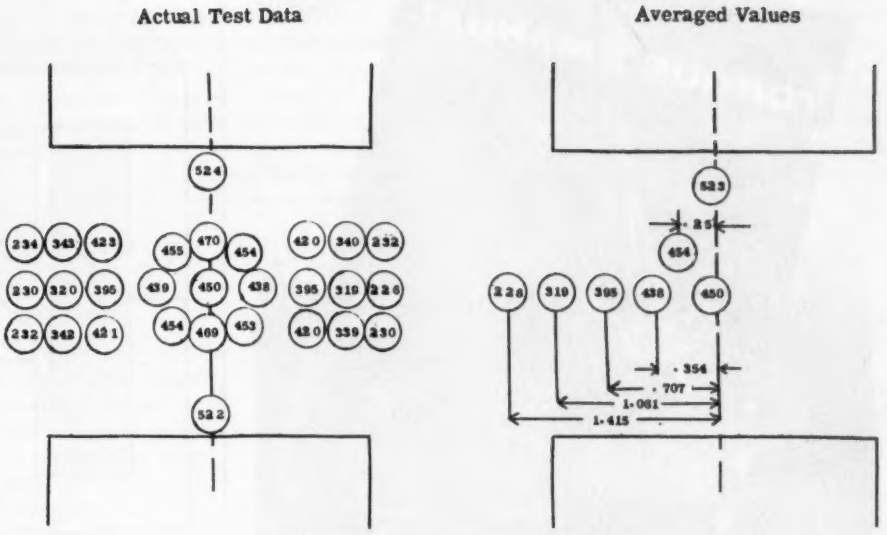


Fig. 3 Photograph of electromagnet illustrating the method of measuring field densities at various points in the air gap.



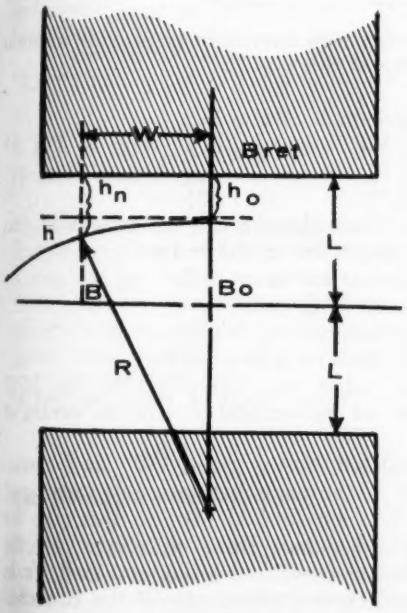


Fig. 5 Illustration of symbols.

DATA AND CALCULATED RESULTS

Horizontal Distance W	Field B	Field Ratio $\frac{B}{B_{ref}}$	Initial Airgap Correction $h_o=(1-\frac{B_o}{B_{ref}})L$	Individual Airgap Corrections $h_n=(1-\frac{B}{B_{ref}})L$	$h=h_n-h_o$	W^2
0	450	.8604	.1396	.1396	.0000	0
.25	444	.8495	.1396	.1505	.0109	.0625
.354	438	.8384	.1396	.1616	.0220	.1253
.500		* .8100	.1396	.1900	.0504	.2500
.707	395	.7553	.1396	.2447	.1051	.4999
1.061	319	.6099	.1396	.3901	.2505	1.1257
1.415	228	.4359	.1396	.5641	.4245	2.0022

* Point obtained from graph interpolation

Fig. 4 Field density distribution in the air gap.

assumption, reducing the air gap on each side of the horizontal center line, along the vertical center line, by 13.96% would increase the value of B_o to that of the reference value. The curve B/B_{ref} was then plotted as in Fig. 6.

This curve depicted how the field density B varied at distances W along the horizontal centerline with respect to the reference field density value, and illustrated the field non-uniformity. To correct this non-uniformity, the assumption that field density varies inversely with length of airgap was again applied. Accordingly the curve of B/B_{ref} also represented the required shape and position of pole face for correction of non-uniformity.

The values of $(1-B/B_{ref})$ L, denoted by h_n, thus represented the airgap corrections that should be designed into the pole face.

Although correcting the pole face to the exact curvature of B/B_{ref} would provide a better field uniformity, it was decided, for ease of manufacture, to approximate this curve with a radius.

To assist in calculating this radius, the term $h = h_n - h_o$ was obtained as tabulated in Fig. 4.

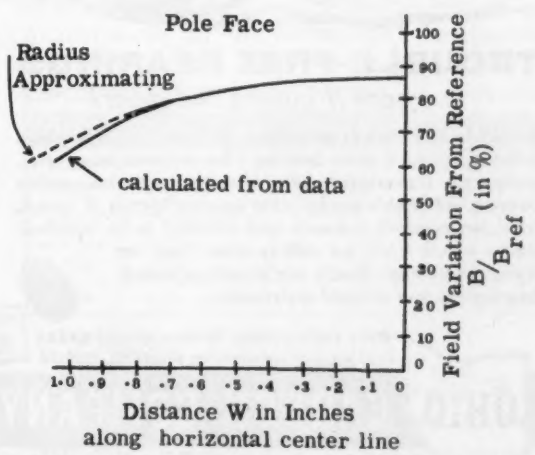
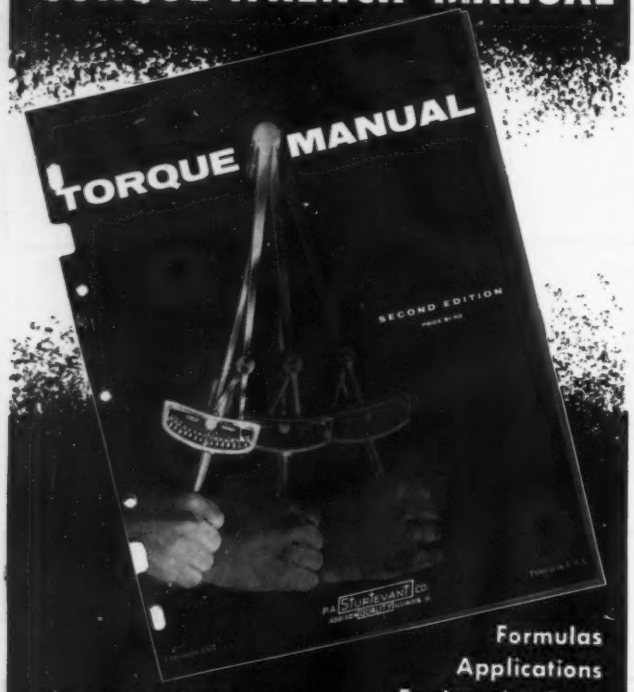


Fig. 6 Variations in field density B along horizontal center line of gap with respect to the reference density B ref.

"TORQUE WRENCH" MANUAL



SENT UPON REQUEST

Formulas
Applications
Engineering Data
Screw Torque Data
Adapter Problems
General Principles

PA STURTEVANT CO.
ADDISON QUALITY ILLINOIS

Manufacturers of over 85% of the torque wrenches used in industry

CIRCLE NO. 51 ON INQUIRY CARD

TROUBLE-FREE BEARINGS

...where it counts the most!

KARAK is a mixture of graphite and other forms of carbon. Self-lubricating, it solves bearing lube problems many times, many ways. It provides freedom of design for the inaccessible bearing. Adaptable grades meet varying factors of speed, load, temperature, pressure, and material to be handled. Unlike metals, it will not melt or seize. It will not distort under heat. Results are greatly extended bearing life and reduced maintenance.

Write factory today for free sample KARAK bearing, and information sheets No. 1164-74.

The OHIO CARBON COMPANY

12508 Berea Road, Dept. 288 Cleveland 11, Ohio

CIRCLE NO. 50 ON INQUIRY CARD

DESIGN TIME SAVER

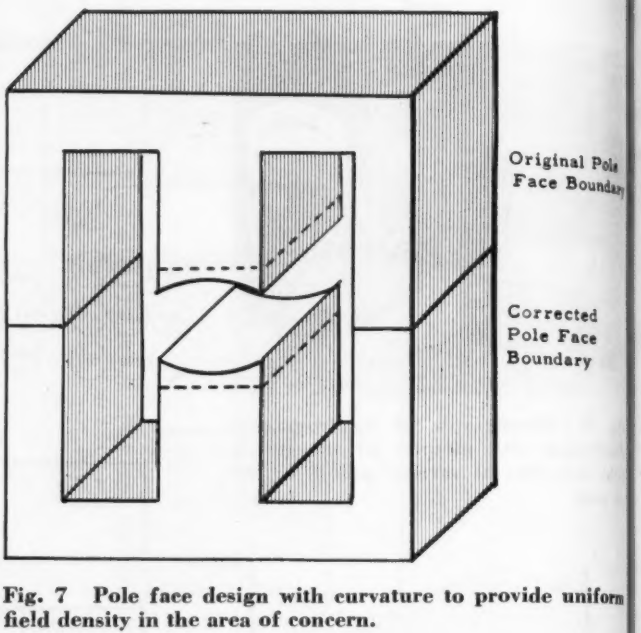


Fig. 7 Pole face design with curvature to provide uniform field density in the area of concern.

The radius is related to h and w by:

$$R^2 = (R-h)^2 + W^2 \qquad (1)$$ (refer to Fig. 5)

or

$$R = W^2/2h + h/2 \qquad (2)$$

The technique used for selecting the radius was to pass a circle through three points on the curve.

Using the general equation of a circle:

$$(x-h)^2 + (y-k)^2 = R^2$$

and the points:

$$(-.5 + .81) \quad (0, .8604) \quad (4.5, + .81)$$

the approximating radius was computed to be 2.505 inches with its center on the vertical axis in the center of the pole face.

Once R was calculated, for a given "W" and corresponding h from Fig. 4, the error between this curve and the required curve was established. To do this, the h's for radius R, were calculated, from equation (1), for various values of W and compared with tabulated h's in Fig. 4 for the required curve to determine if the R chosen provided approximation within the permissible error of $\pm 1\%$.

In this particular design problem, the radius did provide adequate approximation and greatly simplified manufacturing. Fig. 8 illustrates the final pole configuration which provided the required field uniformity.

Circle No. 100 on Inquiry Card.

WORTH FILING

Electroforming

"Current Uses For Electroforming" is a manual for designers incorporating the latest technical information on the process of building a structural part of electro-deposition. Included in the 32-page handbook are chapters on what the electroforming process is, where it is used, "do's and don'ts" for designers, and charts and tables of engineering data.

Source: Allied Research & Engineering Div.
Allied Record Manufacturing Co.
Los Angeles, Cal.

For your copy: Circle No. 232 on Inquiry Card

WORTH FILING

Electronic Modular Construction

A newly revised quick order guide can help design engineers plan and package circuitry. The 20-page booklet lists off-the-shelf components used in making up complete electronic systems. Also included is a new brochure which graphically describes a method of modular construction of electronic units from off-the-shelf components.

Source: Alden Products Company
Brockton, Massachusetts
For your copy: Circle No. 214 on Inquiry Card

Positioning and Program Controls

16 page booklet includes information on: linear and rotary actuators delivering torques from a few inch ounces to 3500 inch pounds; remote positioners from low cost relay types to power transistor units with resolutions to one part in 250,000; machine tool point-to-point position and rate control; punch card formula and program control; and closed loop process control.

Source: Jordan Controls, Inc.
Milwaukee, Wisconsin
For your copy: Circle No. 202 on Inquiry Card.

Flexible Couplings

48-page catalog is a valuable guide in the application of flexible couplings. What is misalignment and how to select a coupling are topics discussed and a classification table of loads is given. Specifications of a great variety of couplings are given along with recommendations in applications.

Source: Thomas Flexible Coupling Co.
Warren, Pennsylvania
For your copy: Circle No. 198 on Inquiry Card.

Sub-Miniature Connectors

Small, ruggedly constructed connectors are made in a variety of contact sizes. Electrical and mechanical ratings meet or exceed applicable paragraphs of MIL-C-5015 and MIL-C-8384. Aluminum hoods, protective shells and patented polarizing screw-locks are also described in a 12-page catalog of specifications and general information.

Source: Continental Connector Corp.
Woodside, New York
For your copy: Circle No. 199 on Inquiry Card.

Variable Speed Pulleys

A full line of variable speed pulleys plus related equipment including compound drives, motor bases and frames, wide V-belts and sheaves, are described in a new 24 page technical catalog. Information includes selection and operating data, horsepower, ratings, dimensions and representative applications for a wide variety of models. The variable speed pullers are the cam-operated type which positively maintain desired speed even under overload conditions. The units range from fractional to 5 hp. with speed ratios from 1.75-1 to 2.6-1.

Source: Hi-Lo Mfg. Co.
Chicago, Illinois
For your copy: Circle No. 209 on Inquiry Card.

Meter-Relays

Specialized expanded scale meter-relays with accuracies almost impossible to achieve with D'Arsonval meter movements alone are described in a new 12-page catalog. Accuracy of these locking contact meter-relays is achieved by adding an expansion network that eliminates the part of the scale not needed and expands the section to be used. Catalog includes typical circuitry and specifications.

Source: Assembly Products, Inc.
Chesterland, Ohio
For your copy: Circle No. 196 on Inquiry Card.

Electrohydraulic Control

"A Guide to Industrial Electrohydraulic Servo Components and Systems," a 20-page booklet, provides engineers with a current summary of the basic principles and applications of electro-hydraulic servocontrol mechanisms. Features of the booklet include description, types and applications of servovalves and an extensive study of typical case histories. These case histories examine specific control problems and the manner in which electrohydraulic controls were used to solve them. Numerous diagrams and drawings illustrate the text and aid in the discussion of various types of units.

Source: Moog Servocontrols, Inc.
East Aurora, New York
For your copy: Circle No. 230 on Inquiry Card.

Daven precision wire wound resistor... Type 1282

makes other miniatures look like giants!

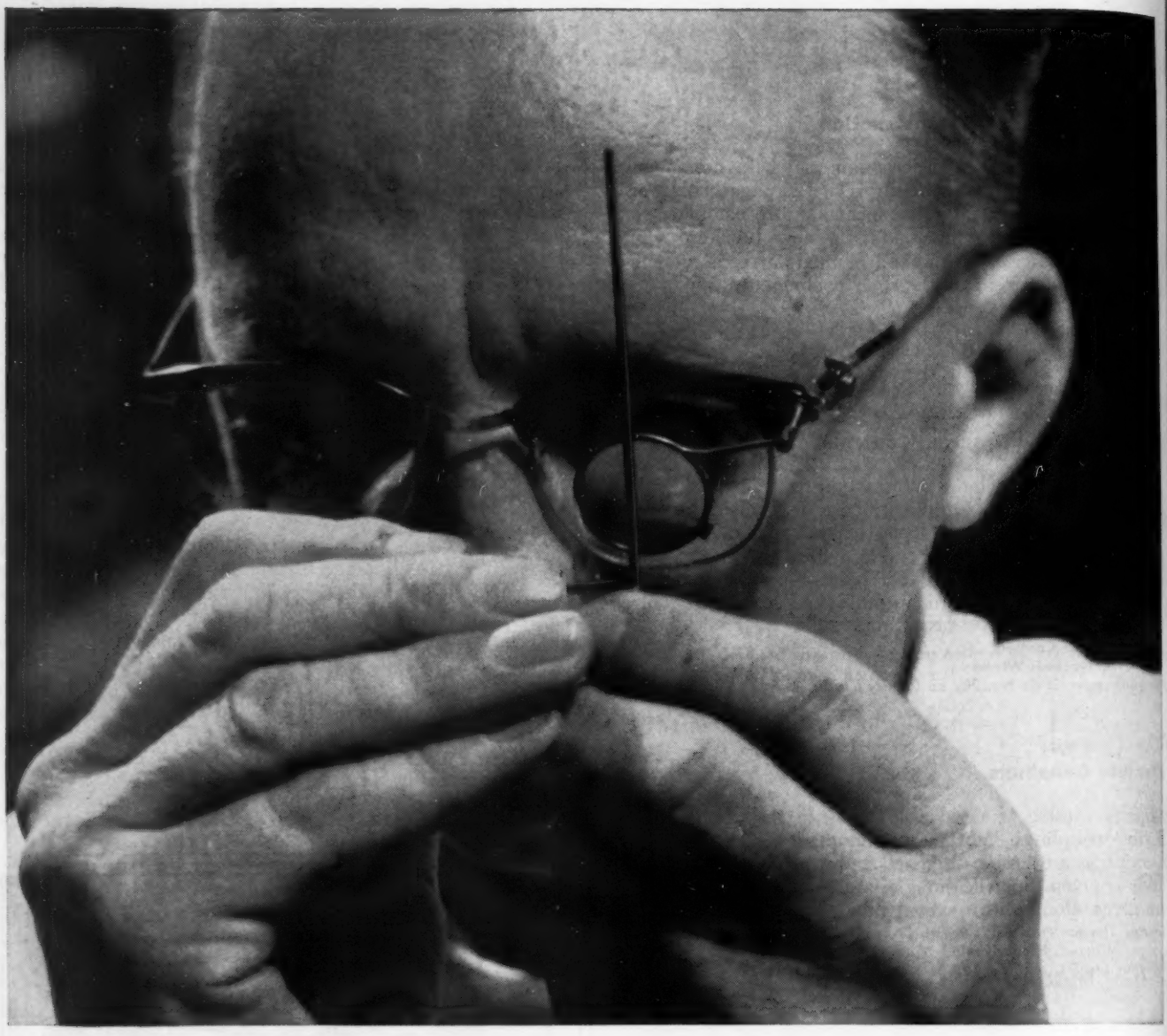
Daven's latest micro-miniature wire wound resistor is the smallest ever made! Type 1282 meets all specs of MIL-R-93B, Amendment 3, except physical size. Available in all tolerances and temperature coefficients.

SOME REPRESENTATIVE DAVEN RESISTORS ARE LISTED BELOW:

Type	Diam	Length	Max Watts	Max Ohms
1250	1/4	1/2	.33	1 megohm
1273	1/4	5/16	.25	400K
1274	3/16	3/8	.25	250K
1282	1/8	1/5	.05	100K
1284	1/4	27/64	.25	1 megohm

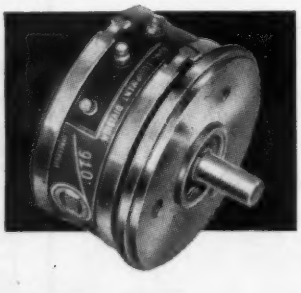
FOR FURTHER INFORMATION WRITE:
THE DAVEN CO.
LIVINGSTON, NEW JERSEY
Today, more than ever, the Daven ⓓ stands for dependability

CIRCLE NO. 52 ON INQUIRY CARD



Constant surveillance is your assurance of Borg reliability

The technician in the photo above is inspecting a .001" wire which is wound around the mandrel he is holding. This hair-like wire will become the resistance element for a Borg 900 Series Micropot Potentiometer. Because the resistance element is the most important single part of any potentiometer, every 900 Series Micropot element is carefully inspected during and after winding . . . one more reason for the Borg 900 Series Micropot reputation for high reliability. Write for complete military and commercial specifications.



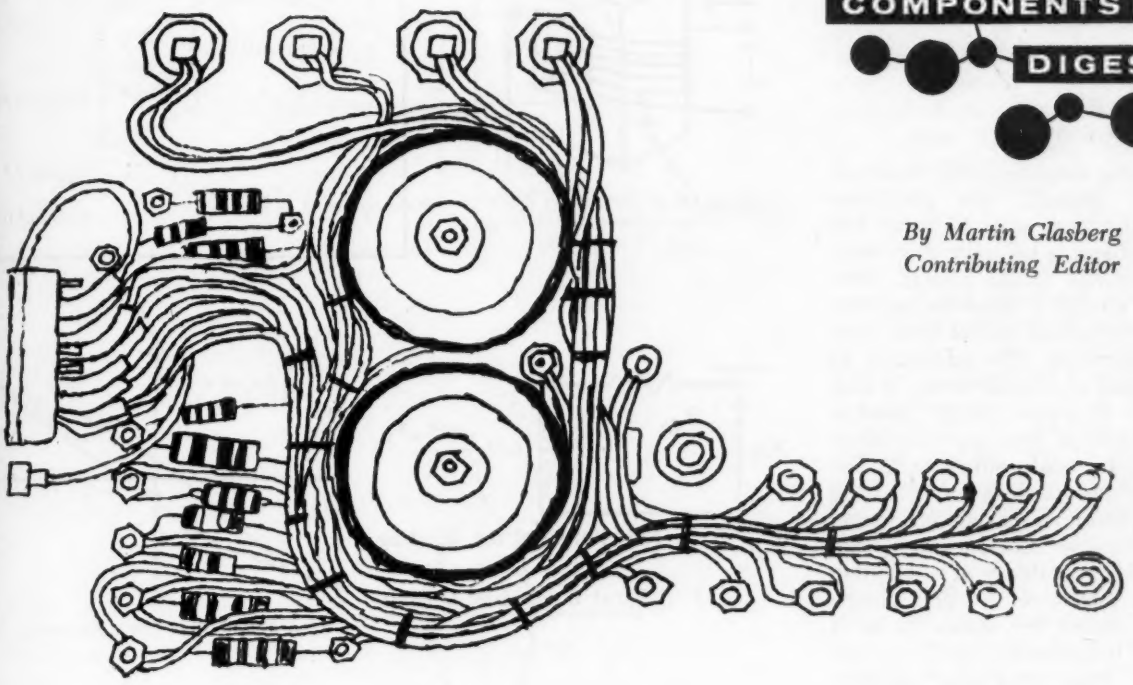
ASK FOR DATA SHEETS
BED-A128, BED-A129 AND BED-A130

BORG EQUIPMENT DIVISION
Amphenol-Borg Electronics Corporation
Janesville, Wisconsin

Micropot Potentiometers • Turns-Counting Microdials • Sub-Fractional Horsepower Motors • Frequency and Time Standards

CIRCLE NO. 53 ON INQUIRY CARD

COMPONENTS DIGEST II



By Martin Glasberg
Contributing Editor

Audio Power Amplifiers

PART III A

In Parts I and II of this Digest, in the January issue, we discussed magnetic amplifiers in a general way and compared their characteristics to those of vacuum tube, transistor, and thyratron amplifiers. In this section, Part IIIA, we develop the fundamentals of magnetic amplifier operation, compare various circuits, discuss their problems, and present a digest of available units.

The term magnetic amplifier or "magamp" is mainly used to describe two closely related devices; saturable reactor circuits and self-saturating reactor circuits. Both these devices depend upon the fact that an unsaturated magnetic core has a very high impedance and a saturated core has a very low impedance. In this way a magamp is similar to a synchronous switch which opens and closes continuously. The output of the amplifier is increased by increasing the average time the switch is closed or, analogously, increasing the average time the magnetic core is saturated.

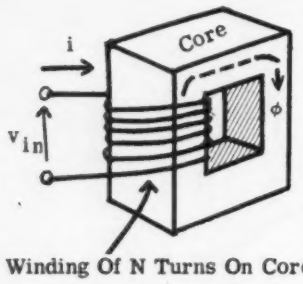
Magamps in the form of saturable reactors were first used around the turn of the century for r.f. modulation. Vacuum tubes, however, quickly replaced magamps in all but the very large power applications, such as theater lighting control. It wasn't until after World War II that the need for small, very rugged, power anplifiers became apparent. Development of transistor amplifiers has filled much of this need, especially since the advent of high power transistors, but magamps are a very strong competitor.

The main emphasis at present is upon self-saturating circuits because of their high power gain to time constant ratio. Since this ratio is constant, an increase in power gain means bandwidth must decrease. This limitation is of prime importance in automatic control where magamps are most useful. Self-saturating devices can also be designed to achieve the maximum bandwidth with the minimum effort.

To balance the great potential of magamps we must consider their liabilities. Foremost is the fact that magamps, as with tyrathrons, amplify by gating portions of the power supply sinewave into the load. The harmonic distortion resulting from this type of output will be very high and only some average value can be made to follow the input. Two phase motors are well suited to this type of signal because, if the reference voltage is a sinewave, the motor will act on only the fundamental of the control voltage. The remaining harmonics will be dissipated in the form of heat. Of course heating in the motor can become a very bad problem. The d-c component of the output signal is also important because it will act as viscous damping in the two phase motor.

Many other problems are based on the fact that the magamp is discontinuous. Even the best self-saturating circuits have a dead time between one-half and one cycle of the carrier frequency. In almost all cases the cores must be matched to each other and selected carefully to fit the supply voltage and frequency, the rectifier characteristics, and the load impedance. This generally means the resulting expense is high. Another effect is that since parameter values are critical, aging or temperature changes can cause a null drift or gain change in the amplifier. Furthermore, as pointed out by Don Martini at Feedback Control, Inc., many times the magamp will affect other equipment by distorting the supply voltage waveform as a function of the point at which power is gated.

COMPONENTS DIGEST



Winding Of N Turns On Core

BASIC RELATIONS

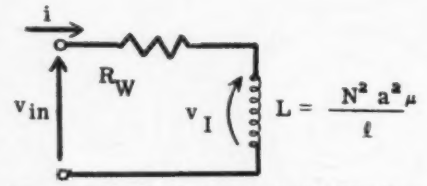
ϕ = flux in core

μ = permeability

$\phi = \frac{Nia^2}{\ell}$ a^2 = cross section

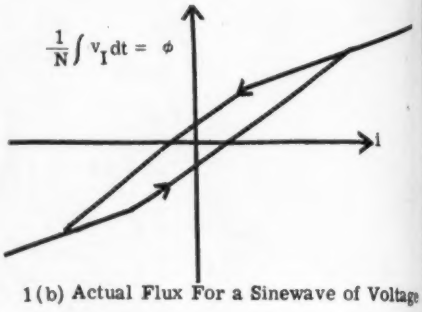
ℓ = length of the magnetic path

$v_I = N \frac{d\phi}{dt}$

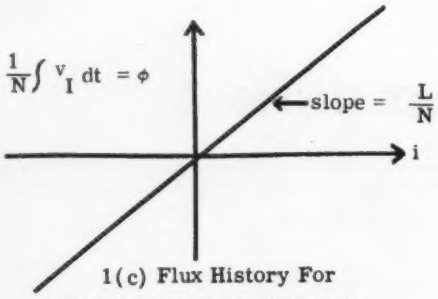


R_W = D. C. Resistance of the Winding

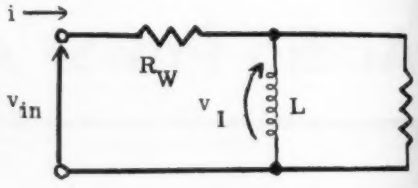
1(a) A First Equivalent Circuit



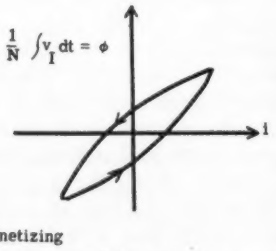
1(b) Actual Flux For a Sinewave of Voltage



1(c) Flux History For The First Equivalent Circuit



1(d) A Second Equivalent Circuit



R_M = Magnetizing Resistance

1(e) Flux History For Second Equivalent Circuit

Fig. 1 Simple choke.

EQUIVALENT CIRCUIT

The magnetic amplifier, and magnetic circuits in general, are nonlinear. Probably the best way to solve this type of problem is by solving an equivalent piecewise linear circuit.. One equivalent circuit is then an approximation to the actual circuit over some range of operation. The advantage of the equivalent circuit, however, is that it is easier or more exactly possible to solve. Quite a few approximations can usually be made either to fit the actual case more exactly or to match the real problem over a different range.

As an example consider the choke in Fig. 1. It is made-up of a winding and a soft iron core. At first glance we would expect the choke to be a pure linear inductance (Fig. 1 a). Applying the basic magnetic relations shown, we find that the resulting inductance is a function of a number of parameters. All the parameters except core permeability, for our purposes, are constant. The permeability is a measure of the increase in magnetic flux in the core for an increase of current in the coil. From physical reasoning we would expect the flux to tend to a limit (saturate) with increasing current. The actual history of the flux for a sinewave of voltage (Fig. 1 b) in fact not only shows saturation, but also shows a double value depending upon the direction of change of flux.

The flux history of the core is said to follow a hysteresis loop where the area within the loop is the energy lost in the core. The linear inductance, no matter what its value, can only be a rough approximation of the choke even over a small range. A much better equivalent circuit is shown in Fig. 1 (d). In this approximation a resistance R_M is made to shunt the inductance and in this way account for the energy lost in the core. It is important to note that even this second approximation is best over only a limited range.

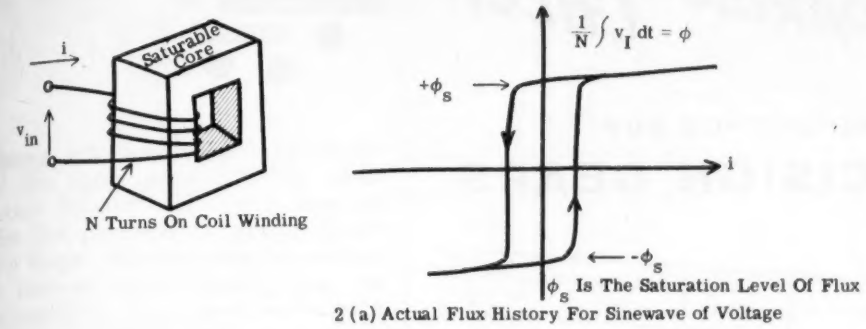
SATURABLE CORES

Had the choke been made of a good saturable core material the flux history would have been similar to Fig. 2 (a). The idea in a choke or transformer is to make the core have a constant permeability (slope of flux-current curve) over the range of expected operation. A saturable core, on the other hand, must have a high permeability until saturation is reached after which the permeability abruptly approaches zero. The approximate inductance of the saturable core will therefore be infinite until saturation and zero thereafter. In this way the saturable core can be made to act like a switch.

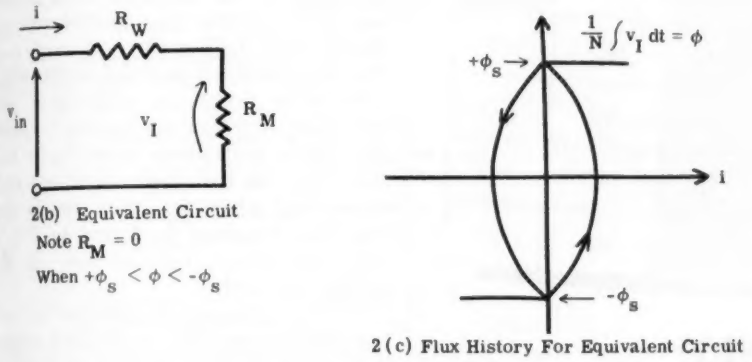
The equivalent circuit in Fig. 2 (b) will be similar to that of the regular choke except that no inductance is present; inductance is infinite. Also, R_M is made to equal zero after the flux in the core reaches the saturation level. The flux history of the equivalent circuit is shown in Fig. 2 (c) and approximates the actual flux curve of Fig. 2 (a) fairly well.

A SIMPLE SATURABLE REACTOR

The simplest possible reactor circuit is shown in Fig. 3 to demonstrate the principles discussed so far. The equivalent circuit is derived exactly as if the core were wound as a normal transformer. The only difference is that the effective inductance of the core is infinite until saturated. Once the equivalent circuit is sketched the solution is almost self-evident (the results, of



2 (a) Actual Flux History For Sinewave of Voltage



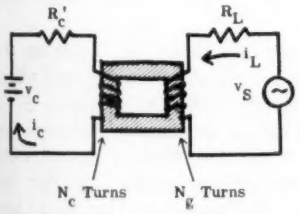
2(b) Equivalent Circuit

Note $R_M = 0$

When $+\phi_s < \phi < -\phi_s$

2 (c) Flux History For Equivalent Circuit

Fig. 2 Choke with a saturable core



R_c' = Control Source Resistance

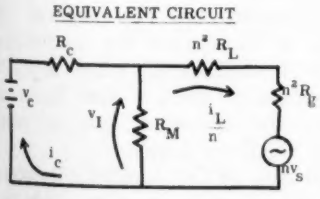
v_c = Control Voltage

v_S = Supply Voltage, $V_S \sin \omega t$

R_L = Load Resist.

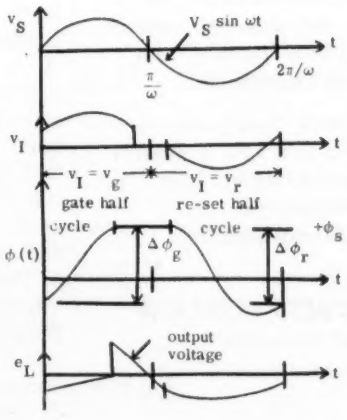
$n = \frac{N_c}{N_g}$

EQUIVALENT CIRCUIT



$R_c = R_c'$ + Twice The d-c Resistance of Control Winding

R_g = d-c Resistance of Gate Winding



$\overline{v_r} = \frac{\omega}{\pi} N_c \Delta\phi_r$

$\overline{v_g} = \frac{\omega}{\pi} N_c \Delta\phi_g$

$\Delta\phi_r = \Delta\phi_g$

$\overline{v_r} = \overline{v_g}$

Bar Means An Average Value

Fig. 3 Simplest saturable reactor circuit.

course, can be no more accurate than the equivalent circuit).

The steady state waveforms for the reactor are shown in Fig. 3. They are obtained from the usual network analysis except that when flux in the core reaches saturation R_M will become a short. Flux in the core is equal to the integral of the voltage across the core, V_1, divided by the number of turns, N, in the coil.

A very important and general conclusion that can be drawn from the waveforms in Fig. 3 is that the average voltage across the core will be the same during the reset half cycle as during the gating half cycle. The reset half cycle is the interval when the flux is receding from saturation and the gating half cycle is the interval when the flux is advancing toward saturation (see Fig. 3). To appreciate the conclusion we must realize the flux change over either half cycle is proportional to the average voltage across the core during that same period.

Therefore, since the flux reaches the saturated value every other half cycle, it decreases during the reset half cycle exactly as much as it increases during the gating half cycle. This means that the flux change in the reset and gating half cycles are equal and, consequently, the average voltages are equal. This point is stressed because it will be used later in this section to solve more complicated magamp circuits.

PARALLEL CONNECTED REACTOR CIRCUIT

A more practical and commonly used circuit is shown in Fig. 4. This circuit is generally called a parallel connected saturable reactor. Its main advantage over the circuit in Fig. 3 is that by using two cores with opposing windings, the power supply voltage, e_s, is not seen in the control circuit until one of the cores saturates. In this way the current flowing when both cores are unsaturated is limited by the high magnetizing resistance R_M and not by the control circuit resistance R_c.

The output of the amplifier is the voltage developed across the load resistor, as shown in Fig. 4. The normal procedure and the one used here, is to measure the output as an average over a half cycle of the supply frequency. There are two reasons for using an average: first, it will produce a straight forward solution, and second, it represents the case where the output is demodulated (rectified and filtered).

On the other hand, if the output is used to drive a two phase motor, the fundamental component of the output is the important factor since only it can produce torque. The relationship be-

COMPARISON CHECK

BEFORE YOU BUY

PRECISION GEARS

QUALITY FEATURES	APPCO GEARS	Competitor A	Competitor B
Strict adherence to all A.G.M.A. specifications	YES	NO	NO
All numbers of teeth available in aluminum and stainless steel	YES	YES	NO
Consecutive tooth sizes in all pitches	YES	NO	YES
Choice of four (4) bore sizes in flat gears at no cost	YES	NO	NO
Tapes supplied at no cost on *all* precision gears	YES	NO	NO
Blank configurations proportional to their diametral pitch	YES	NO	NO
Gears "Mylar" sealed on trays to protect the precision	YES	NO	NO

ONLY

APPCO *Certified* STOCK GEARS

OFFER ALL THESE FEATURES!

You get extra value in every APPCO Precision Gear. Extra value in the finest qualities not offered by other gear manufacturers. Compare them before you specify or buy!

Every APPCO Gear is made to A.G.M.A. specifications. Held to tolerances. Certified to precision-fit shaftings, and components. Each gear is sealed in plastic to be free of dirt, dust or corrosion and assure its arrival at your plant "factory-fresh" ready to use on the most critical assemblies.

APPCO Certified Precision Stock Gears are available in 32, 48, 64, 72, 96 and 120 diametral pitches of 14½° and 20° pressure angles. Spur gears, pin or clamp type . . . hubless and anti-backlash. For complete technical data and catalog write to . . .

ATLAS PRECISION PRODUCTS COMPANY
Division of Prudential Industries
Philadelphia, Pa.

APPCO

PRUDENTIAL INDUSTRIES

APPCO

APPCO

CIRCLE NO. 54 ON INQUIRY CARD

tween the fundamental, the averag value, and the wave shape will b discussed later. The parallel reactor circuit in Fig. 4, however, will onl produce a non-reversible signal an two such circuits must be used t drive a two phase motor. Problems re sulting from using two non-reversibl a-c amplifiers will also be discusse later.

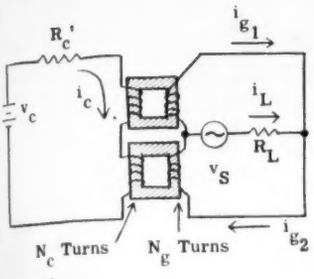
The equivalent circuit for the para lel connected reactor is shown in Fig 4. It allows us some insight into th operation of the amplifier. One impor tant point is that the control voltag during each half cycle, aids one co toward saturation and holds the oth core from becoming saturated. Th core that is aided alternates betwee the upper and lower core each ha cycle. In each half cycle, then, one co is resetting while the other core is ga ing. This situation is shown in Fig. with the lower core shown in th gating half cycle.

Another important observation w can make from the equivalent circu is that the resetting voltage of one co is affected by the gating voltage on th other core. Also, the voltage develope across R_c by the current in the contr circuit affects the reset voltage. Th last point complicates the problem be cause the load current will flow throug the control circuit when one co saturates.

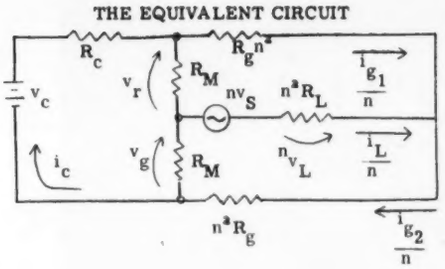
To bring all these observations to gether into a chain of cause and effe we can draw a block diagram as i Fig. 4. This is extremely valuable be cause it shows the three internal fee back loops characteristic of the se urable reactor circuits. The first, loo A, is a positive feedback of the gati voltage to the resetting voltage. Th second, loop B, is the negative fee back of the load current into the co trol circuit, and the third, loop C, the negative feedback due to the cu rent drawn through the core ma netizing resistance, R_M.

The remainder of this Section w attempt to show that the underly purpose in designs of more sophi cated magamp circuits has been eliminate the effects of one or mo of these feedback loops.

In the case of the parallel connec reactor circuit, the performance c now be evaluated by reducing the bl diagram as in equation 4.1. It is i portant to note that this solution sults in a dfference equation. A cha in the average output voltage w



THE EQUIVALENT CIRCUIT



$n = \frac{N_c}{N_g}$

R_c' = Control Source Resistance

v_c = Control Source Voltage

v_S = Supply Voltage = $V_S \sin \omega t$

R_L = Load Resistance

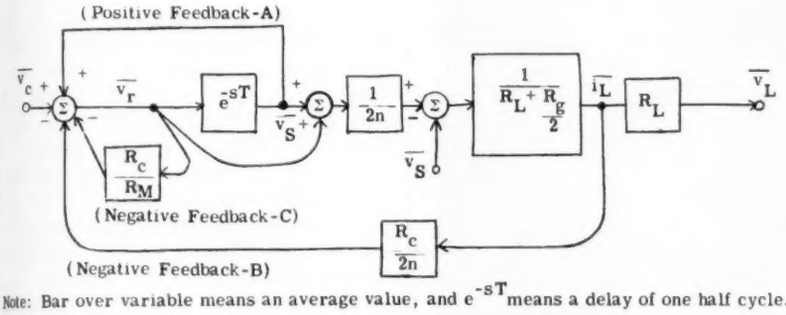
$R_c = R_c'$ + Twice d-c Resistance of Control Winding

R_g = d-c Resistance of Gate Winding

R_M = Magnetizing Impedance of Core

Note: Equivalent circuit is shown for the half cycle when the lower core is gating and the upper core is re-setting. In the next half cycle the functions will reverse.

BLOCK DIAGRAM



Note: Bar over variable means an average value, and e^{-sT} means a delay of one half cycle.

REDUCING SIGNAL FLOW DIAGRAM

Now $R_M >> R_L >> R_g$ For Good Amplifier

$\overline{v_L}(n)$ Is The Average Output Voltage During The n^{th} Half Cycle.

$$(4.1)\quad \overline{v_L}(n) = \frac{2n R_L}{R_c + 4n^2 R_L}\left[\overline{v_c}(n) + \overline{v_c}(n-1)\right] + \frac{4n^2 R_L - R_c}{4n^2 R_L + R_c}\,\overline{v_L}(n)$$

The Laplace Transform

$$(4.2)\quad \overline{v_L}(s) = \frac{2n R_L}{R_c + 4n^2 R_L}\,\overline{v_c}\left[1 + e^{-sT}\right] + \frac{4n^2 R_L - R_c}{4n^2 R_L + R_c}\,\overline{v_L}\left[e^{-sT}\right]$$

Linearization

$$(4.3)\quad \text{Let } e^{-sT} \cong \frac{1}{1+sT}\ ;\ T = \pi/\omega \text{ (half period)}$$

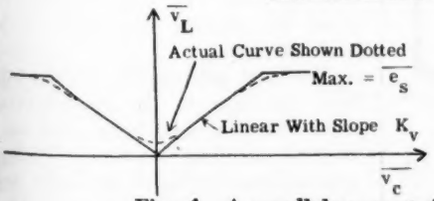
$$\frac{\overline{v_L}(s)}{\overline{v_c}(s)} = \frac{2n R_L}{R_c}\,\frac{\frac{\pi}{2\omega}s + 1}{\frac{\pi}{2\omega}\left(1 + \frac{4n^2 R_L}{4n^2 R_L}\right)s + 1}$$

if $R_L >> R_c$

$$(4.4)\quad \frac{\overline{v_L}(s)}{\overline{v_c}(s)} = \frac{2n R_L}{R_c}\,\frac{1}{\left(\frac{\pi}{2\omega}\,\frac{4n^2 R_L}{R_c}\right)s + 1} = \frac{K_v}{Ts+1}$$

$$K_v = \frac{2n R_L}{R_c} \qquad T = \frac{2\pi n^2 R_L}{\omega R_c}$$

OUTPUT VERSUS INPUT



Example of Waveshape

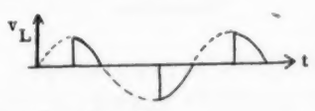


Fig. 4 A parallel connected reactor circuit.

BASIC BUILDING BLOCKS FROM KEARFOTT

PRECISE ANGLE INDICATOR

Consisting of an angle position indicator, motor and servo amplifier, this small, versatile, rack panel mounted unit provides angular position indications for laboratory, production and field use. Input signals proportional to unknown angular position of synchro device being measured are resolved as an error voltage, which is amplified and used to drive an internal servo loop to null. Counter mechanism then provides direct visual readout of angular position.

TYPICAL CHARACTERISTICS

Input Signal: S_1, S_2, and S_3 of external synchro transmitter.

Repeatability: Within 0.6 minute in either a clockwise or counterclockwise direction for any angular position.

Readability: 0.5 minute through full range from zero to 360° Rotation is continuous.

Accuracy: ± 6 minutes in the standard unit. Other accuracies available on request.

Sensitivity: 0.5 minutes maximum.

Slewing Speed: Phase sensitive, 180° in 7 seconds.

Input Voltages: 115 volts, single phase, 400 cycles, 23 VA max.

Size: Standard Rack Mounting—1¾" x 9½" x 8½"

Write for complete data.

GP KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

CIRCLE NO. 55 ON INQUIRY CARD

CIRCLE NO. 93 ON INQUIRY CARD

NEW BRISTOL PRESSURE SWITCH

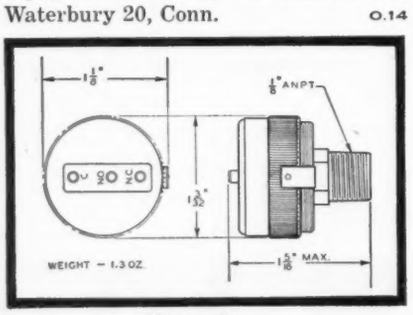
Here's a subminiature pressure switch that incorporates the superb reliability characteristics of larger Bristol pressure switches. Yet, it's both miniature in size and it's adjustable.

It's the Bristol Type C2060 . . . with six models covering ranges from 2-15 psi, absolute, to 20-200 psi gauge.

Easy pressure adjustment. You can change pressure settings easily and simply, without tools. Just turn the top portion of the switch. A strong ball detent holds settings positively even under severe vibration and shock.

Withstands shock, vibration, and acceleration in excess of MIL-E-005272B requirements. SPDT snap-action contacts are rated at 5 amps, 125vac, 60 cps; 2.5 amps d-c resistive load.

Get complete specifications on the new Bristol adjustable pressure switch today. Simply write for Bulletin AV 2015. The Bristol Company, Aircraft Equipment Division, 181 Bristol Road, Waterbury 20, Conn. O.14



Dimensions

BRISTOL FINE PRECISION INSTRUMENTS FOR OVER SEVENTY YEARS

See us in Booths 141-142 at the Southwest IRE Show.

CIRCLE NO. 42 ON INQUIRY CARD

therefore, occur in half cycle incremental steps, as we would expect. We should stress the fact that there was actually no linear time constant in the same way that there was actually no inductance in the equivalent circuit.

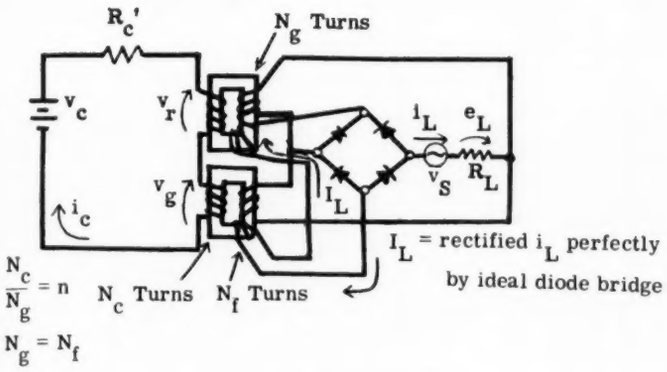
The solution of the parallel connected circuit can be carried a step further if we are only interested in the envelope of the output voltage and not in its exact incremental value. In this case, the performance function can be linearized as in equation 4.3. As a final result, the linearized voltage gain and time constant are given in equation 4.4. Figure 4 also contains a sketch of the output versus the input voltage for the equivalent circuit and for an actual amplifier. It is interesting to note that the output is insensitive to the sign of the input voltage.

Before leaving saturable reactors we must mention that other circuits besides parallel connections are used. Two other configurations are the series connected and the shunt connected saturable reactor circuit. In fact the series connected circuit is somewhat more popular because of its greater power gain to bandwidth ratio. We chose to discuss the parallel connected circuit because of its similarity to other more advanced circuits. For more information on saturable reactor circuits the reader is referred to the many A.I.E.E. Transaction papers and to H. F. Storm's book, "Magnetic Amplifiers."

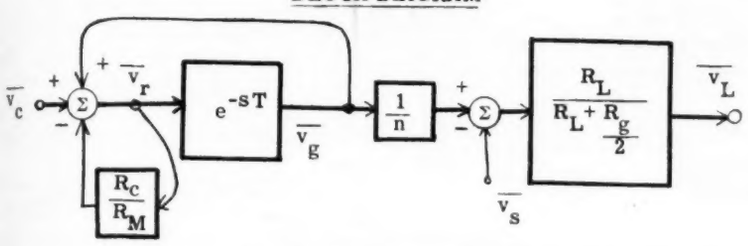
FEEDBACK

To increase the gain in the parallel connected reactor circuit we can use three alternatives from the block diagram in Fig. 4. First reduce the control resistance, R_c; second, as in any amplifier, use positive external feedback; and third, cancel the negative feedback loop B by blocking the load current from flowing into the control circuit. This last option is actually the most popular and will lead to a whole class of circuits described as being self-saturating.

The first alternative is not too practical because R_c is dependent upon the control source resistance and the control winding resistance. With positive voltage feedback, however, we can obtain the same effect as a decrease



BLOCK DIAGRAM



REDUCING SIGNAL FLOW

$$(5.1)\qquad \overline{v_L}(n) = \frac{R_M}{R_M + R_c}\,\overline{v_L}(n-1) + \frac{R_M R_L}{n(R_M + R_L)\left(R_L + \frac{R_g}{2}\right)}\,\overline{v_c}(n-1)$$

Laplace Transform

$$(5.2)\qquad \frac{\overline{v_L}(s)}{\overline{v_c}(s)} = \frac{R_L R_M}{n(R_L + \frac{R_g}{2})(R_M + R_c)} \qquad \frac{e^{-sT}}{1 - \frac{R_M}{R_M + R_c}\,e^{-sT}}$$

Linearizing

$$e^{-sT} \cong \frac{1}{1+sT} \quad ; \quad T \cong \pi/\omega$$

$$(5.3)\qquad \frac{\overline{v_L}(s)}{\overline{v_c}(s)} = \frac{R_L R_M}{n(R_L + \frac{R_g}{2})R_c} \times \frac{1}{\frac{\pi}{\omega}\left(\frac{R_M + R_c}{R_c}\right)s + 1}$$

if $R_g << R_L$

$$(5.4)\qquad \frac{\overline{v_L}(s)}{\overline{v_c}(s)} = \frac{R_M}{n R_c} \times \frac{1}{\frac{\pi}{\omega}\left(\frac{R_M + R_c}{R_c}\right)s + 1} = \frac{K_v}{\tau s + 1}$$

$$K_v = \frac{R_M}{nR_c}$$

$$\tau = \frac{\pi(R_M + R_c)}{\omega R_c}$$

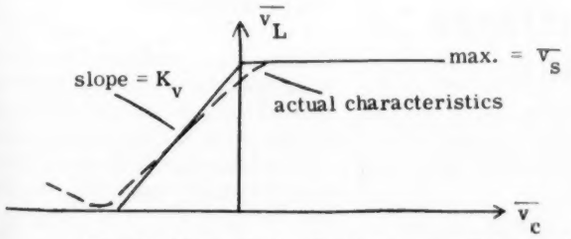
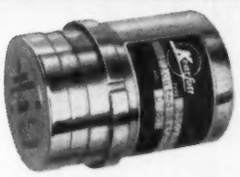


Fig. 5 Magnetic feedback in a parallel circuit.

BASIC BUILDING BLOCKS FROM KEARFOTT



FLOATED RATE INTEGRATING GYROS

Specifically designed for missile applications, these Kearfott miniature gyros operate efficiently at unlimited altitudes. Their outstanding accuracy and performance make them superior to any comparably-sized units on the market. Hermetically sealed within a thermal jacket, these gyros are ruggedly designed and completely adaptable to production methods. Performance characteristics that are even more precise can be provided within the same dimensions.

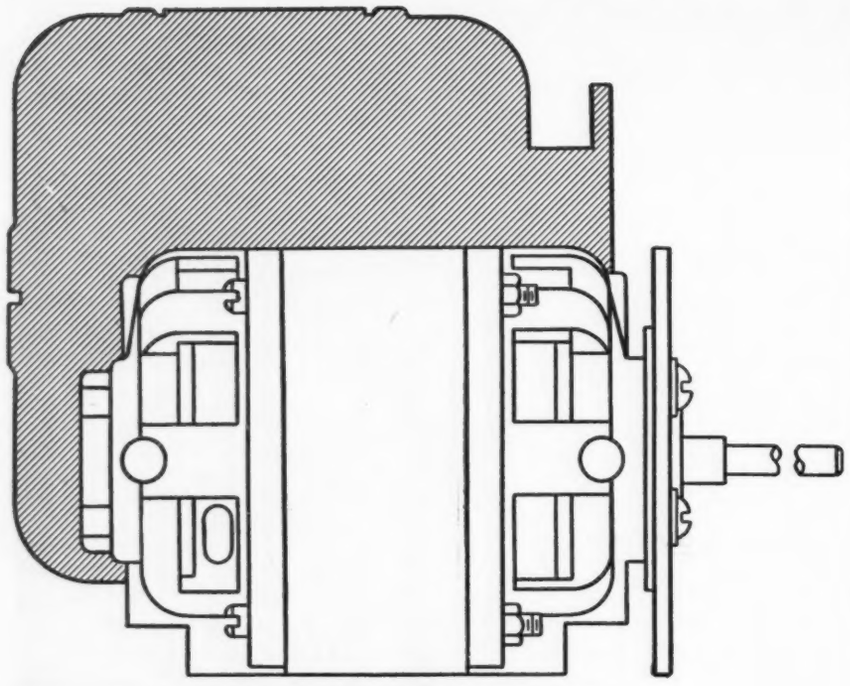
TYPICAL CHARACTERISTICS

Mass Unbalance:
Along Input Axis: 1.0°/ hr maximum untrimmed
Standard Deviation (short term):
Azimuth Position: 0.05°/hr
Vertical Position: 0.03°/hr
Drift Rate Due to Anisoelasticity
Steady Acceleration: .015°/hr./g² maximum
Vibratory Acceleration: .008°/hr./g² maximum
Damping:
Ratio of input angle to output angle is 0.2
Characteristic Time: .0035 seconds or less
Weight: 0.7 lbs.
Warm-Up Time: 10 minutes from –60°F
Life: 1000 hours minimum

Write for complete data.

GP KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

CIRCLE NO. 56 ON INQUIRY CARD



Holtzer-Cabot Solves Fractional H.P. Motor Problems

50% MORE TORQUE

in a smaller, lighter motor

A leading instrument manufacturer* using 3¾" diameter motors needed an increase in torque output of 50%. This increase in torque had to be gained without using a larger motor or increasing the overall weight of the instrument.

To solve this problem, Holtzer-Cabot Engineers designed a smaller, 2⅞" diameter motor with improved features which resulted in much greater efficiency.

The new motor is completely mechanically and electrically interchangeable with the larger unit formerly used and provides the desired 50% increase in torque, while saving about 40% in weight and space. The motor, designated as Type R-29, is an ideal power source for recording instruments, timers, medical instruments, office equipment, etc. A permanent split-capacitor type, available as an induction or synchronous motor, the R-29 is manufactured in both 2-pole and 4-pole designs, each in three stacking lengths. Horsepowers range from 1/75 to 1/30.

*Name on request.

Write for Information! Holtzer-Cabot specializes in the design and manufacture of fractional horsepower motors for all types of applications. For complete details on the motor described above, and a copy of "Key Factors in Selecting AC Motors for Instrument Service" write direct or use Readers Service Card.

For more information, write, or use Readers' Service Card.

Sales — Service Representatives in Principal Cities throughout the World

HOLTZER-CABOT MOTOR DIVISION
NATIONAL PNEUMATIC CO., INC.
125 Amory Street, Boston, Massachusetts

Designers and manufacturers of mechanical, pneumatic, hydraulic, electric and electronic equipment and systems

CIRCLE NO. 61 ON INQUIRY CARD

COMPONENTS DIGEST

in R_c without changing any of the actual impedance values. The second alternative therefore seems quite useful. We should mention that negative voltage feedback will act to increase the effective input impedance but will also reduce the null drift. On the other hand, positive current feedback can be obtained in the magamp quite easily by adding an extra winding to the cores so that the output current will aid the control current reset the flux. Positive current feedback, moreover, has the advantage of increasing the power gain to time constant ratio while voltage gain increased the power gain only as much as it increased the time constant.

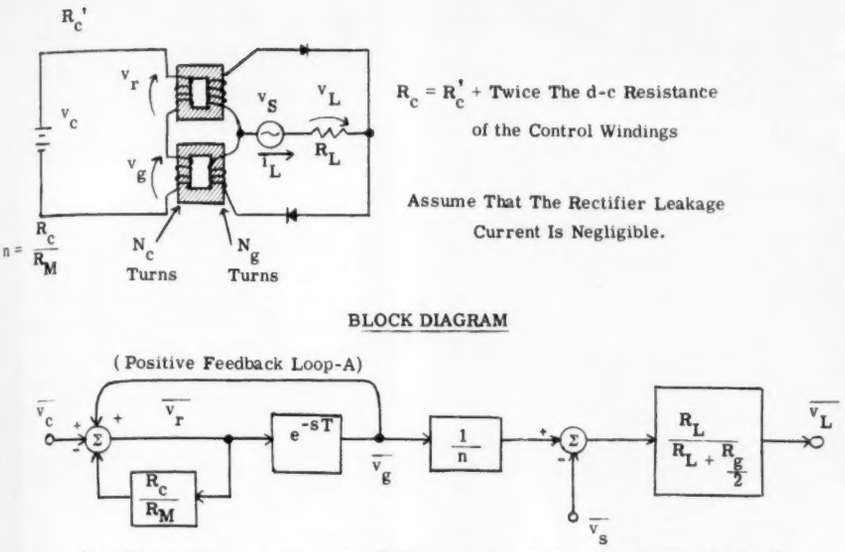
An example of positive current feedback is given in Fig. 5 as it could be applied to the parallel connected reactor circuit. In the example the number of turns in the feedback winding, N_f, is set equal to the number of turns in the gate winding, N_g. The resulting signal flow diagram shows that the negative feedback loop B has been eliminated. In other words the effect of the load current in the feedback windings just cancels the effect of the load current in the control circuit.

Another important result of the current feedback can be seen in equations 5.1 and 5.2; this is the increased emphasis upon R_M. We must remember that R_M, the magnetizing resistance, is probably the most inaccurate element in the equivalent circuit and only roughly approximates the core losses. Consequently, as R_M becomes more important the results become less accurate. Another problem is rectifier leakage which could allow a partial return of the negative feedback.

Probably the most popular feedback circuits are a combination of positive current feedback and negative voltage feedback for stability. The term "self-balancing" is generally used to describe the effect of the two feedbacks. For more information on these circuits the reader is referred to W. A. Geyger's book, "Magnetic-Amplifier Circuit."

SELF-SATURATION

Under the heading "Feedback" we mentioned three ways of increasing the gain of the parallel connected saturable reactor circuit. The third alternative of blocking the load current from the control circuit must still be discussed.



Note that doubler acts like a parallel connected reactor with magnetic feedback and $N_f = N_g$. Therefore from Fig. 5:

$$(5.4) \qquad \frac{\overline{v_L}(s)}{\overline{v_c}(s)} = \frac{R_M / nR_c}{\frac{\pi}{\omega}\left(\frac{R_M + R_c}{R_c}\right)s + 1}$$

Fig. 6 Doubler circuit.

Actually it turns out that the third alternative is the simplest. The load current can be blocked from the control circuit of the parallel connected reactor by introducing two amplifiers as in Fig. 6. The resulting circuit is generally called a doubler or "amplistate."

As we would expect, the block diagram of the circuit in Fig. 6 shows that the negative feedback loop B is eliminated. The performance of the doubler will, therefore, be the same as the feedback circuit in Fig. 5. The average output voltage of the doubler will also follow the input voltage in the manner shown in Fig. 5. From this output-versus-input curve we can see that maximum output occurs for zero control voltage. To obtain maximum output, each of the cores must stay saturated for its gating half cycle. This type of circuit, therefore, requires no external voltage to reach complete saturation and, consequently, is termed "self-saturating."

The equations describing the performance of the feedback circuit in Fig. 5 apply equally well to the doubler, and the linearized transfer function, equation 5.4, is repeated in Fig. 6.

FAST RESPONSE

So far we have discussed saturable reactor and self-saturating reactor circuits. Historically, there is one further development in magamps, inspired by the relatively slow response of the other circuits. From the block diagram for the doubler, shown in Fig. 6, we can easily see that to increase the response we must eliminate the positive feedback loop—A. To achieve this result the gate voltage of one core must be isolated from the reset voltage on the other core. With no positive feedback loop, the doubler would have an ideal response of one half cycle dead time.

Two ways are generally used to block this positive feedback. The first technique is to actually use rectifiers to isolate the control windings of the cores from each other. The second method is to make both cores gate in the same half cycle. This second technique achieves the desired result because, even though the reset voltages interact, there can be no feedback between the gate voltage of one core and the reset voltage of the other core.

Examples of both methods are given in Fig. 7. Figure 7(a) illustrates the first technique. It shows a reversible half wave circuit, quite popular for small two phase motors. The input is ac and the bias is arranged so that, for zero control, each core fires for a quarter of a cycle as sketched in Fig. 7(a). When each core fires at exactly the same point in alternate half cycles, no fundamental component is present in the output voltage and no torque is produced in the two phase motor. To produce a fundamental component in the output, the cores must fire at different times in their respective half cycles as is shown in Fig. 7(a).

The a-c control voltage adds to the

BASIC BUILDING BLOCKS FROM KEARFOTT

20 SECOND SYNCHRO

This synchro, just one of a broad line offered by Kearfott, provides the extreme accuracy required in today's data transmission systems. Kearfott synchro resolvers enable system designers to achieve unusual accuracy without the need for 2-speed servos and elaborate electronics. By proper impedance, matches up to 64 resolver control transformers can also operate from one resolver transmitter.

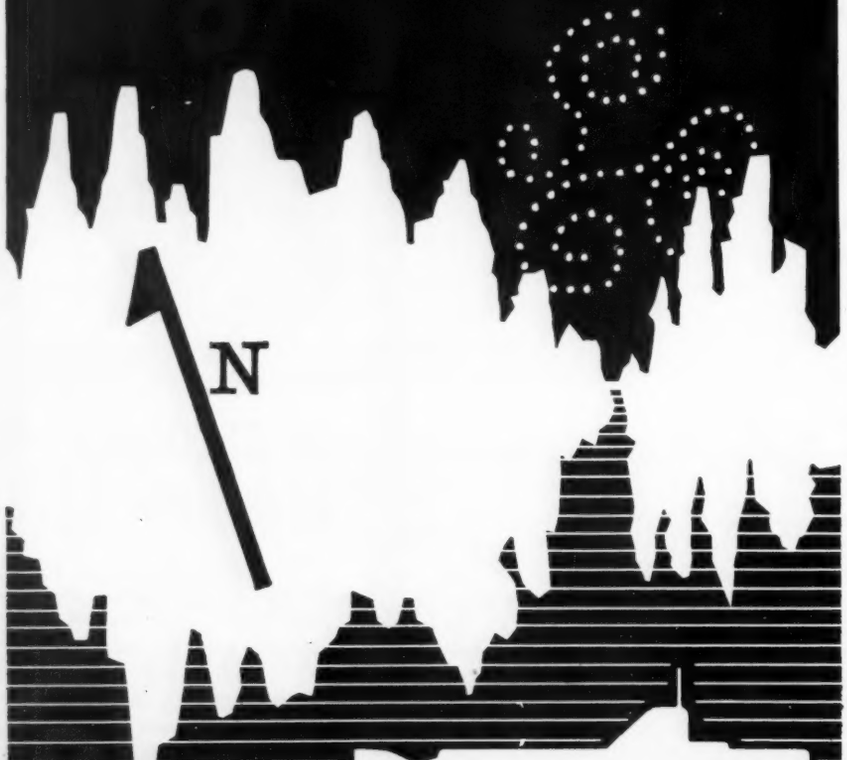
TYPICAL CHARACTERISTICS	SIZE 25	
		Control
Type Resolver	Transmitter	Transformer
Part Number	Z5161-001	Z5151-003
Excit. Volts (Max.)	115	90
Frequency (cps)	400	400
Primary Imped.	400/80°	8500/80°
Secondary Imped.	260/80°	14000/80°
Transform. Ratio	.7826	1.278
Max. Error fr. E.Z.	20 seconds	20 seconds
Primary	Rotor	Stator

Write for complete data.

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

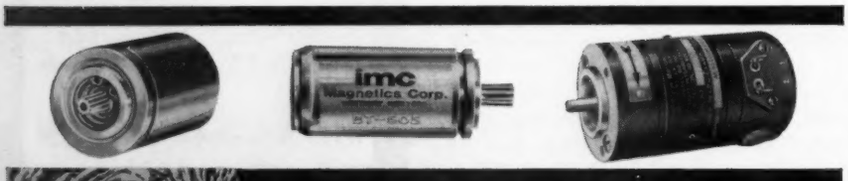
CIRCLE NO. 57 ON INQUIRY CARD

imc
SERVO MOTORS



SMALLER, LIGHTER, TOUGHER, MORE RELIABLE

Whether your servo application is in the challenging under-water environments of the history-making Skate or in the severe blast-off environment of the Polaris, you now can design your equipment or system smaller and better with an IMC servo ■ New advances in sub-miniaturization and motor performance ensure top operating characteristics for your systems applications. Size 5 through 18, high torque-to-inertia ratio, encapsulated for extra ruggedness, broad range of gear ratios, meet latest MIL environmental specifications ■ IMC engineers are ready to assist you in your servo design needs. Take advantage of their special servo know-how. Chances are they will save you time and money . . . plus provide you with a motor that completely fulfills your particular requirements ■ Write for additional technical information to:



imc Magnetics Corp.
570 MAIN STREET/WESTBURY, LONG ISLAND/NEW YORK/EDGEWOOD 4-7070

CIRCLE NO. 92 ON INQUIRY CARD

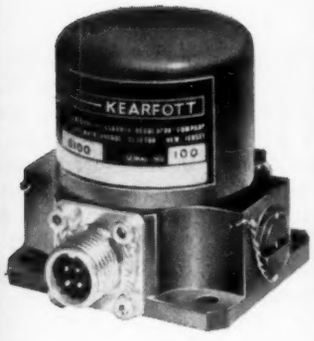
reset voltage on one core and subtracts on the other core. In this way one core fires sooner in its half cycle than does the other. The time delay in the performance function, however, will be more like one full cycle because both cores must react before the fundamental component is effected.

Figure 7(b) shows an example of the second technique for fast magamps. In this case the output occurs during the same half cycle whenever one core fires before the other core. With the same current flowing in each half of the centertapped output transformer, no flux is developed in the transformer core, and no voltage is developed across the load resistance. For zero control voltage the bias is generally set so that both cores fire at the same time and conduct simultaneously for about a quarter of each alternate half cycle, as in Fig. 7(b). The reason for having quiescent simultaneous conduction is that a more linear gain is achieved. This raises a problem, however, since high currents will be flowing during the simultaneous conduction interval. The solution is to design the windings to withstand the high current, keep the simultaneous conduction to a minimum, and to place a limiting resistor, R_s, in series with the supply voltage.

The control of the amplifier can be designed for either dc or ac and is achieved by having the control voltage aid the reset of one core and retard the reset of the other core, exactly as in the circuit of Fig. 7(a). In this way one core has less reset and fires early while the other core, which was reset to a lower flux level, must saturate later. The waveforms in Fig. 7(b) show that, when only one core is conducting, current flows through one leg of the centertapped primary and a voltage is developed across the load. It is quite apparent from the example that the amount and phase of the power supplied the load is dependent upon the relative saturating times of the two cores.

One problem is that, once one core saturates and current flows through one leg of the primary, a voltage will be induced in the other leg of the primary winding. This induced voltage will add to the voltage across the unsaturated core and increase the rate of flux build-up, saturating the core more quickly. Since the output is determined by how long the unsaturated core takes

BASIC BUILDING BLOCKS FROM KEARFOTT



ELECTROHYDRAULIC SERVO VALVE

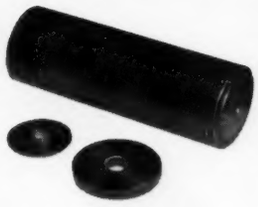
Kearfott's unique approach to electrohydraulic feedback amplification design has resulted in a high-performance miniature servo valve with just two moving parts. Ideally suited to missile, aircraft and industrial applications, these anti-clogging, 2-stage, 4-way selector valves provide high frequency response and proved reliability even with highly contaminated fluids and under conditions of extreme temperature.

TYPICAL CHARACTERISTICS

Quiescent Flow ..... 0.15 gpm
Hysteresis .. 3% of rated current
Frequency Response
3 db @ 100 cps
Supply pressure....500 to 3000 psi
Temperature-Fluid & Ambient
−65° F to +275° F
Flow Rate Range .... .3 to 10 gpm
Weight ..... 10.5 ounces

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT



FERRITES

Kearfott's Solid State Physics Laboratory formulates, fires and machines permanent magnet ferrite materials of various compositions. Typical high-efficiency array utilizes Kearfott PM-3 ferrite material with specially designed pole pieces to produce a design both smaller and lighter than other arrays of equivalent magnetic field strength. Because magnets may be custom engineered to specific requirements, user is not restricted to stock magnet types, thereby providing greater latitude in parameters for focusing arrays. Pole pieces may also be provided according to specification, with the added assurance that, because of special Kearfott design techniques, B axial magnetic fields approximately 10% higher than those generally obtained in standard types may be produced.

TYPICAL CHARACTERISTICS

Peak Magnetic Field Strength	1200 gauss
Period	0.560 in.
Length	5.64 in.
Inside Diameter of Pole Pieces	0.400 in.
Outside Diameter	2.0 in.
Weight	3.2 pounds

Write for complete data.

BASIC BUILDING BLOCKS FROM KEARFOTT

INTEGRATING TACHOMETERS

Kearfott integrating tachometers, special types of rate generators, are almost invariably provided integrally coupled to a motor. They feature tachometer generators of high output-to-null ratio and are temperature stabilized or compensated for highest accuracy integration and rate computation. Linearity of these compact, lightweight tachometers ranges as low as .01% and is usually better than ± .1%.

TYPICAL CHARACTERISTICS

	Size 11 (R860)
Excitation Voltage (400 cps)	115
Volts at 0 rpm (RMS)	.020
Volts at 1000 rpm (RMS)	2.75
Phase shift at 3600 rpm	0°
Linearity at 0-3600 rpm	.07
Operating Temperature Range	−54° +125°

Write for complete data.

Miniature Floated Gyro

Precise Angle Indicator

20 Second Synchro

KEARFOTT DIVISION
GENERAL PRECISION INC.
LITTLE FALLS, NEW JERSEY

Midwest Office: 23 W. Calendar Ave., La Grange, Ill.
South Central Office: 6211 Denton Drive, Dallas, Texas
West Coast Office: 253 N. Vinedo Avenue, Pasadena, Calif.

Engineers: Kearfott offers challenging opportunities in advanced component and system development.

ON VALVES
CIRCLE NO 58 ON INQUIRY CARD

ON FERRITES
CIRCLE NO. 59 ON INQUIRY CARD

ON TACHOMETERS
CIRCLE NO. 60 ON INQUIRY CARD

MUIRHEAD

GEARHEADS

Backlash after 500 hours' running! Less than 45 mins.

These gearheads are designed to mount on the front of standard Bu-Ord, SAE, and RAE size 11 motors, and can accommodate the different shaft lengths of these types. They have the same overall diameter and mounting arrangements as the motors to enable them to be mounted in a similar manner. Types are available modified for use with size 08 or size 10 motors, or on their own as speed reducers. In the design particular attention has been paid to robust construction and long life, ball bearings are used throughout and the materials and dimensions of the gears have been chosen to give minimum amount of wear.

PERFORMANCE SPECIFICATION

INPUT. The input gear meshes with the 13 tooth 120 DP. pinion of either standard Mark 14 motors, size 11 motors to SAE ARP, 497 or size 11 motors to RAE, EL, 1789. OUTPUT. The standard output shaft is splined 21 teeth 120 DP. with thread for shaft nut and drive washer. Alternatively plain shafts up to $\frac{7}{16}$" diameter may be supplied, or a 13 tooth 120 DP. pinion suitable for cascading 2 or more gearheads.

Maximum power output, torque not to exceed 80 oz in	$\frac{1}{4}$ watt
Maximum backlash after 500 hrs running with $\frac{1}{4}$ watt load	45 minutes measured on output shaft by reversing 8 oz in torque
Starting torque	0 2 gm cm
Inertia at motor shaft	0.02 g cm²
Operating temperature range	—54°C to +100°C
Tropical exposure test DTD 1085B	Withstands 28 days exposure

RATIOS. A number of ratios up to 600:1 are available as standard and these will probably satisfy most requirements:—Types G11A, 600:1; G11B, 300:1; G11C, 150:1; G11D, 60:1; G11E, 24:1; G11G, 40:1. Other ratios can be provided.

MUIRHEAD

Precision Electrical Instruments

MUIRHEAD INSTRUMENTS INC.,
441 Lexington Avenue, New York 17, N.Y., U.S.A.
Telephone: Murray Hill 2-8131
MUIRHEAD & CO. LIMITED, Beckenham Kent, England
Telephone: Beckenham 4888
MUIRHEAD INSTRUMENTS LIMITED, Stratford, Ontario, Canada
Telephones: 3717 & 3718

497

CIRCLE NO. 62 ON INQUIRY CARD

COMPONENTS DIGEST

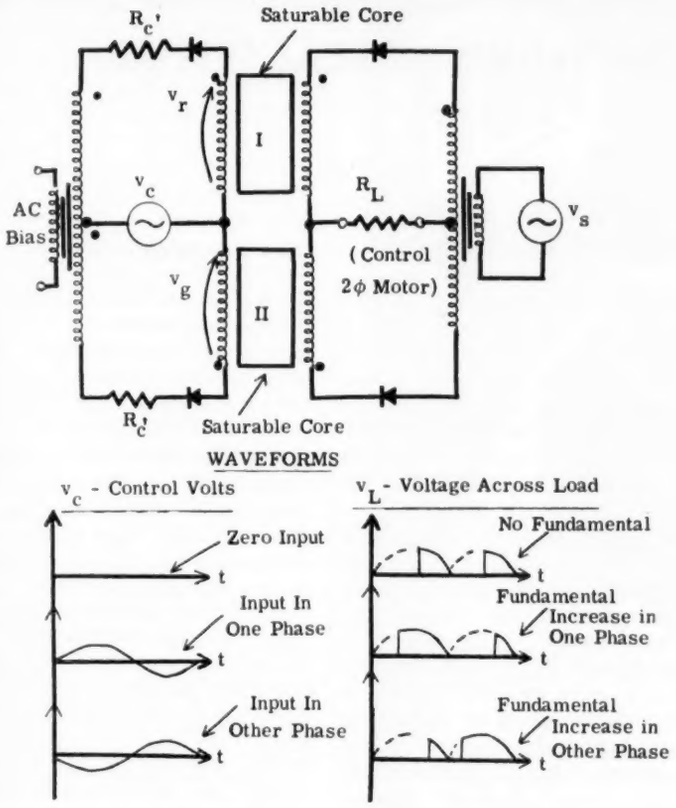
to fire once the other core fires, th induced voltage will decrease the gai The limiting resistance, R_s, howeve will cure this situation because, whe current flows in one core, a voltage developed across R_s in a direction buck the induced voltage. In fact, $R_s = N^2R_L/4$, (N = output tra former ratio) the induced voltage w be completely cancelled.

An important point from Fig. 7(is that, since the output can occur on every alternate half cycle, the averag dead time must be nearly one cycle the supply frequency. To achieve th minimum of a half cycle dead time, full wave magamp circuit must be use The full wave circuit, however, woul mean exactly double the circuit in Fig 7 (b) as well as extra problems fro feedback between the two sets of con trol windings.

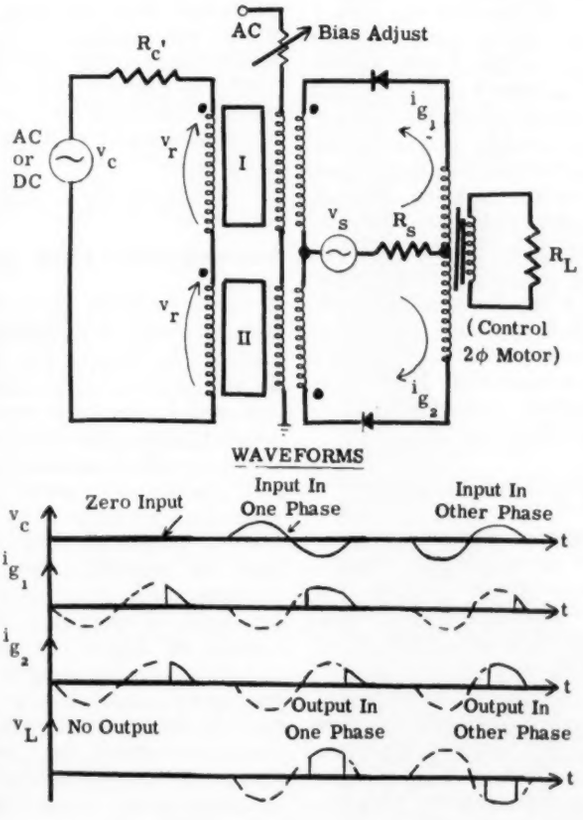
CONCLUSION

In this article we discussed the funda mentals of magamp operation, the tech niques for analysis, and a number o the basic circuits. A great deal o credit must be given Mr. Thorlief Knu trud, R.C.A. Laboratories in Burlingto Mass., for his many ideas on magneti amplifiers. Mr. Knutrud will also be principle contributor to a second par of the Magnetic Amplifier Component Digest which will cover the quantita tive analysis of the most popular cir cuits and the comparison of these cir cuits on a practical basis, emphasizin the actual problems arising in thi application. In addition, the relation ship between average value, wave shape, and Fourier components will b presented.

A summary of manufacturer's data on audio amplifiers, both transistorized and magnetic, scheduled for this issue has been postponed for inclusion with the second Part of the Magnetic Amplifier Components Digest. This postponement is in the interest of more inclusive coverage. If not yet submitted, data on your Companies' units is still welcome for inclusion in these summary charts.



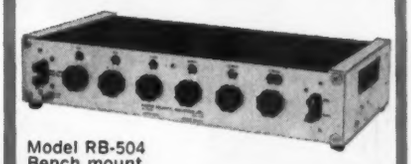
7(a) Control Of Cores Isolated From Each Other



7(b) Both Cores Gate In The Same Half Cycle

Fig. 7 Fast Magamps

North Atlantic Series RB500 Ratio Boxes



Model RB-504
Bench mount

Measure A.C. Ratios From −0.11111 To +1.11111...with accuracy to 1 ppm

With any of North Atlantic's RB500 Ratio Boxes you can now measure voltage ratios about zero and unity—without disrupting test set-ups.

And—a complete range of models from low cost high-precision types to ultra-accurate ratio standards — in portable, bench, rack mount, binary and automatic stepping designs—lets you match the model to the job.

For example, characteristics covered by the RB500 Series include:

Frequency: 25 cps to 10 kc.
Accuracy: 10 ppm to 1.0 ppm
Input voltage: 0.35f to 2.5f
Input impedance: 60 k to 1 megohm
Effective series impedance: 7.5 ohms to 0.5 ohms
Long life, heavy duty switches

Name your ratio measurement and its probable there's a North Atlantic Ratio Box to meet them — precisely. Write for complete data in Bulletin 11J.

Also from North Atlantic
...a complete line of complex voltage ratiometers...ratio test sets... phase angle voltmeters

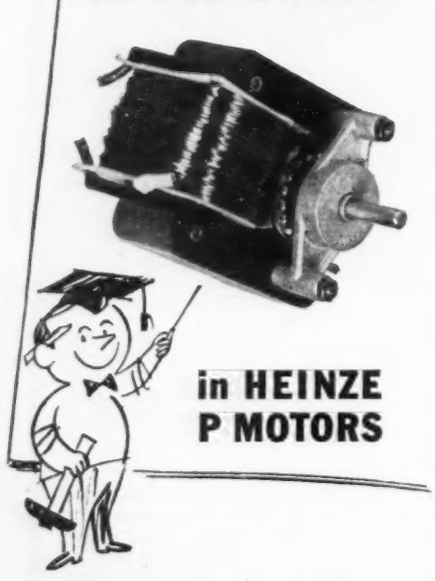
NORTH ATLANTIC
industries, inc.
Terminal Drive, Plainview, L. I., N. Y.
OVerbrook 1-8600

CIRCLE NO. 63 ON INQUIRY CARD

put HEINZE in your designs

P

IS FOR PROFIT



in HEINZE P MOTORS

You profit from exceptional low price and trouble-free performance in Heinze P Motors. These single coil 2 pole induction motors have a wide variety of applications, including pumps, fans, projectors, vending machines, space heaters, toys and appliances. Seven standard models have horsepower ratings of 1/500, 1/375, 1/250, 1/150, 1/100, 1/80 and 1/50 — for continuous duty. They provide slightly better ratings for intermittent duty. Free speed is 3400 rpm. Voltage is 115 or 220, 50/60 cycle. Rotation is CW or CCW.

Send coupon for new catalog.

HEINZE ELECTRIC COMPANY
685 Lawrence St.
Lowell, Massachusetts

SUB-FRACTIONAL HORSEPOWER MOTORS AND BLOWERS

Heinze Electric Company, Dept. ED
685 Lawrence St., Lowell, Mass.

Please send catalog on Heinze Sub-Fractional Horsepower Motors.

Name & Title.....
Company.....
Street & No.....
City & State.....

CIRCLE NO. 64 ON INQUIRY CARD

NEW ELECTROMECHANICAL COMPONENTS FOR ELECTROMECHANICAL SYSTEMS

13 Bit Digital Encoder

A new shaft-position digital encoder with 13 bit binary output employs a unique, non-contacting magnetic readout. Only bearings and gears affect life thus permitting operation in any environment, at speeds up to 10,000 rpm, and with any number of readouts without effect. Only passive circuitry is involved in readout. The new encoder is expected to have broad applications in digital control and data-logging equipment where encoders previously were limited by unreliability, poor environmental resistance, and short operational life. Parallel output is in binary code and total count is reached with 64 turns of the input shaft. Lead-lag head arrangements permit minimum external decision circuitry. The readout method employs subminiature, ferrite toroids mounted above, but not touching, code tracks of magnetized spots on barium ferrite discs. Two disks are used a 2^7 disk connected to a 2^6 disk through a 64:1 gear reduction. As a toroid readout head enters the magnetic field of the code spot, it saturates and its impedance drops. When the head is interrogated by a constant current pulse train, an output is obtained only when the head is unsaturated, i.e. outside the influence of a code spot. Because of the singular geometry of the field and toroid, no emf or spurious pulses are generated when the shaft is rotating, and there is no shaft load. Preloaded, stainless steel ball-bearings afford excellent operation in all environments. ASCOP, Princeton, N. J.

Circle No. 164 on Inquiry Card

Rugged Miniature Potentiometer

½" diameter ten-turn potentiometer designed to meet or exceed the environmental requirements of Mil-E-5272B and MAS 710 is available in all conventional resistance values as well as in nonlinear versions. Low-leakage construction, stop torque limits of 25 in. oz. and temperature performance from −55° to +125°C qualify this little unit for the most demanding applications. Available in linearity to .05%, the potentiometer, for its size, is said to be the most accurate available. Analogue Controls, Inc., Hicksville, N.Y.

Circle No. 256 on Inquiry Card

Tiny Precision Switch

Weighing less than 1/28th of an ounce, a precision switch is said to be the lightest switch of its type. Size reduction is made possible by the use of a unique, snap-acting, "W-blade" element, a design which lends itself to miniaturization. The envelope dimensions of the unit are 0.320 inch diameter by 0.440 inch long. The subminiature switch has been especially designed for applications which require a true hermetically sealed unit of the smallest and lightest configuration possible, combined with high reliability for aircraft, missile and electronic use. Hermetic sealing is accomplished by applying the techniques of seam or stitch welding to switch assembly. Welding eliminates solder flux contamination and contributes to miniaturization by requiring less volume for the weld than for solder. Terminals are brought out through a fused seal to make the assembly completely environment free. Prior to being hermetically sealed, the precision calibrated switch is filled with a dry, inert gas to ensure reliability for dry circuit applications. Spencer Products, Texas Instruments Inc., Metals and Controls Div., Attleboro, Mass.

Circle No. 163 on Inquiry Card

Vane-Operated Limit Switch

A newly designed vane-operated limit switch which is one-third smaller in size, can be front or top operated with a vane opening wider than the previous model. The new switch will operate approximately one-third less than the previous model, making the vane-operated switch only slightly higher in price than a conventional limit switch. Models are available with normally open or normally closed, single-pole contacts, with or without an indicating light. A mounting plate can be rotated 90 degrees to permit flexible mounting arrangements at the time of installation. Another major design feature is the encapsulation of internal components inside the metal enclosure. Operating life is expected to be considerably longer than lever switches when used with conventional low current relays. General Electric Co., Schenectady, New York.

Circle No. 194 on Inquiry Card

Brushless Generator

Excitation power in a brushless synchronous motor generator is produced and rectified in the rotating assembly, eliminating all brushes and slip rings. All rotating parts are assembled on a common shaft supported at the end by two sealed-for-life ball bearings. Elimination of all frictional surfaces virtually prevents wear on parts, while complete absence of copper and carbon dust normally produced by generator brushes greatly reduces maintenance costs. The 400 cycle generator is said to incorporate electrical design advances including low harmonic distortion, good voltage balance with unbalanced load, low voltage transients with sudden load changes, fast voltage recovery on load changes, and unity input power factors. Leach Corp., Compton, Cal.

Circle No. 95 on Inquiry Card

Rotating Transformer

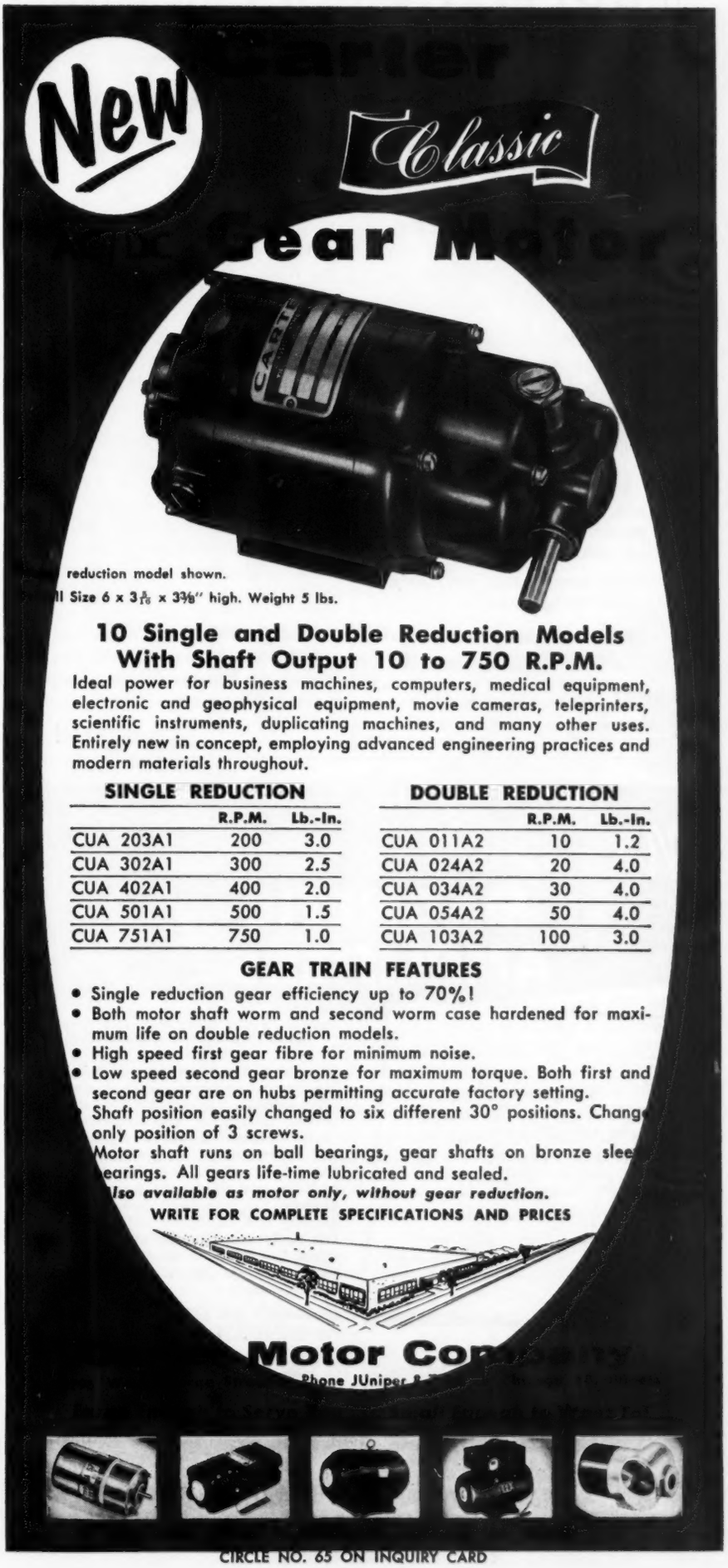
Rotating transformer can be used in a system for providing controlled angular rotation in exact relation to the rotation of the shaft of the rotating transformer. The device operates from an input of 1 phase 60 cycles and is capable of driving positioning motors at torques up to 1 pound-foot. It can be driven at speeds from zero to 600 rpm and the positioning motor will follow in exact relation to the shaft speed of the rotating transformer. There is no torque reaction between positioning motor and rotating transformer so that less than 1 inch-pound of torque to the transformer will provide torques up to 1 foot pound from the positioning motor. B. A. Wesche Electric Co., Cincinnati, Ohio.

Circle No. 180 on Inquiry Card

Stepping Switch

A 22-pole, two position, hermetically-sealed stepping switch that weighs only 2 lbs. 1 oz. meets MIL-E-5272A specs for shock, vibration, extreme temperatures, salt spray and acceleration. It is enclosed in a container with an atmosphere of dry nitrogen that protects it from moisture, dust, fungus, etc. Current at rated coil voltage is 3.5 amps; normal rated voltage, 28 vdc; approximate switching rate, under 30 milliseconds; contact rating, ½ amp resistive at 110 vac, 2½ amps resistive at 28 vdc; dielectric, 1200 vrms coil to case; dielectric switch rating, 500 vrms; life, 1 million steps minimum; duty cycle, ∞ and leakage rate, 1 atmospheric cc of air per year or less per inch of sealed joint, plus header rate, G. H. Leland, Dayton, Ohio.

Circle No. 176 on Inquiry Card


New
Classic
reduction model shown.
ll Size 6 x 3 5/16 x 3 3/8" high. Weight 5 lbs.
10 Single and Double Reduction Models
With Shaft Output 10 to 750 R.P.M.
Ideal power for business machines, computers, medical equipment, electronic and geophysical equipment, movie cameras, teleprinters, scientific instruments, duplicating machines, and many other uses. Entirely new in concept, employing advanced engineering practices and modern materials throughout.
SINGLE REDUCTION
R.P.M. Lb.-In.
CUA 203A1 200 3.0
CUA 302A1 300 2.5
CUA 402A1 400 2.0
CUA 501A1 500 1.5
CUA 751A1 750 1.0
DOUBLE REDUCTION
R.P.M. Lb.-In.
CUA 011A2 10 1.2
CUA 024A2 20 4.0
CUA 034A2 30 4.0
CUA 054A2 50 4.0
CUA 103A2 100 3.0
GEAR TRAIN FEATURES
• Single reduction gear efficiency up to 70%!
• Both motor shaft worm and second worm case hardened for maximum life on double reduction models.
• High speed first gear fibre for minimum noise.
• Low speed second gear bronze for maximum torque. Both first and second gear are on hubs permitting accurate factory setting.
• Shaft position easily changed to six different 30° positions. Change only position of 3 screws.
• Motor shaft runs on ball bearings, gear shafts on bronze sleeve bearings. All gears life-time lubricated and sealed.
Also available as motor only, without gear reduction.
WRITE FOR COMPLETE SPECIFICATIONS AND PRICES
CIRCLE NO. 65 ON INQUIRY CARD

PROJECT AND DESIGN ENGINEERS

America's leading manufacturer of silver-zinc batteries seeks qualified engineers to share in its phenomenal growth.

PROJECT ENGINEERS

with 5-10 years' experience. Must know "weapons systems" concept, be able to assume complete project responsibility. Battery experience helpful but not required.

DESIGN ENGINEERS

with 5-10 years' experience in mechanical and/or electromechanical design.

Salary commensurate with ability. Liberal company benefits.

Send resume, salary required, to

Director of Professional Employment

YARDNEY ELECTRIC CORP.

40 Leonard St., New York 13, N. Y.

ELECTROMECHANICAL COMPONENTS

Rotary Segment Switch

Enclosed in standard RR11 servo mount anodized aluminum housing, this switch can be externally adjusted to open or close at any point within 0° to 355°. Limited adjustable range such as 0° to 180° and 2 pole types can also be made. Ambient range is −50 to +150C and voltage breakdown is 1000 vac. Life is 50 million cycles depending on current and load. Precision Line, Inc., Maynard, Mass.

Circle No. 103 on Inquiry Card

Magnetic Clutch-Brake

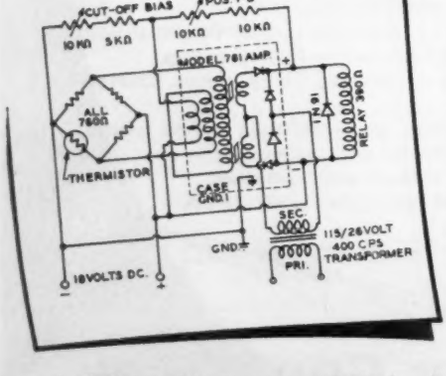
In a miniature clutch-brake combination both clutch and brake are magnetically set. When the current is on the clutch magnet only, the clutch operates and vice versa. Current can be turned off both magnets for free wheeling. Available in any d-c voltage up to 90 volts d-c, has a 1.55 current rating and 8 lbs-in. torque on both clutch and brake side. Stearns Electric Corp., Milwaukee, Wisconsin.

Circle No. 104 on Inquiry Card

Now . . . CONTROL TEMPERATURES TO 0.1° C. WITH *RELIABLE*

MAGNETIC AMPLIFIERS!

Typical 60 CPS Relay Magnetic Amplifier. (400 CPS Models available, too!)



Now, by using Acromag's NEW Relay Magnetic Amplifiers, you can design ultra-reliable temperature controls. In the schematic, the amplifier detects a one microwatt DC signal from the thermistor bridge and controls the power relay. You can vary the pull-in and drop-out points, and change the set-point temperature, quickly and easily by adjusting the two resistors. You can also measure small DC voltages or currents, and control relays from sub-microwatt DC signals.

All models are available from stock for IMMEDIATE DELIVERY . . .

Write, on your company letterhead, for your copy of new Engineering Bulletin #70 describing these new ultra-reliable units.

acromag INCORPORATED

TWX: SOUTHFIELD 970-U

22515 TELEGRAPH RD. SOUTHFIELD (DETROIT), MICH.

PHONE: ELGIN 7-0030

CIRCLE NO. 67 ON INQUIRY CARD

Codewriter

An electronic data input and output machine known as the Codewriter prints characters serially and provides the man-machine coupling to data processing and data handling equipment. The Codewriter is capable of discrete line or binary connection to the basic data handling unit or media creation equipment. Both alpha-numeric and numeric-only printout is available. The output creates a permanent record of complete or exception data for variables such as volume, pressure and temperature. Other applications include logging of laboratory test results and production variables as shaft rotation, weight and quantities. Royal McBee, Industrial Products Div., W. Hartford, Conn.

Circle No. 166 on Inquiry Card

Eddy Current Dampers

New dampers produce smooth damping torque by transmitting input force through a precision gear train which rotates a disc through a permanent high intensity magnetic field. This action generates an eddy current field in the disc. Resultant force of the two fields opposes the motion of disc in direct proportion to the input speed with zero hysteresis, minimum starting torque and an optimum linear relationship.

All models are qualified to the requirements of MIL-E-5272A. Because the eddy current damper is self-contained, requiring no power source and is both non-friction, non-hydraulic it is especially suited to remote, isolated installations where long, trouble-free performance is required. Hydro-Aire Co., Burbank, Cal.

Circle No. 248 on Inquiry Card

Solenoid Lock for Rotary Switches

Designed for use where it is important that circuit-control settings be changed only by authorized personnel or in a prescribed sequence, a solenoid locking mechanism can now be furnished with multi-pole rotary switches. Mechanism can be provided to lock every position of the rotary switch so that no setting can be changed until the solenoid lock is released; or they can be provided with some positions locked and the rest free for local control. Release can be effected by energizing the solenoid or where fail-safe protection is required by de-energizing the solenoid. Units are available for 12-24-115 volt dc operation and can be impregnated to meet MIL-T-152. Electro Switch Corp., Boston, Mass.

Circle No. 102 on Inquiry Card

Sub-Miniature Trimming Pot

Designated the TVR-050 series, a new sub-miniature trimming potentiometer available in 14 standard resistance ranges from 10 ohms to 50K, features a molded plastic case for high dielectric strength. Unique insulating boots on the leads reduce breakage and provide better separation. Basic power rating is 1 watt. The units meet mil specs for temperature, vibration, shock and humidity. Other features include worm and gear adjustment, with high friction loading to eliminate back-lash, and circular resistance element to provide high resolution and thermal stability. Wells Industries Corp., North Hollywood, Cal.

Circle No. 173 on Inquiry Card

Modular In-Line Switch

A new panel switch, called the Digiswitch, replaces ten-position, or octal, switch units of the rotary type. Panel Space requirements are reduced so that designers can mount four times as many Digiswitches in the normal space required for rotary switch elements. The new device is finger controlled and provides for ten-position, single-pole and double-pole, binary coded decimal with variations, and octal 0,1,2,4 coded outputs. In-line readout of the Digiswitch reduces reading errors and simplifies switch setting. The Digitran Co., Pasadena, Cal.

Circle No. 184 on Inquiry Card

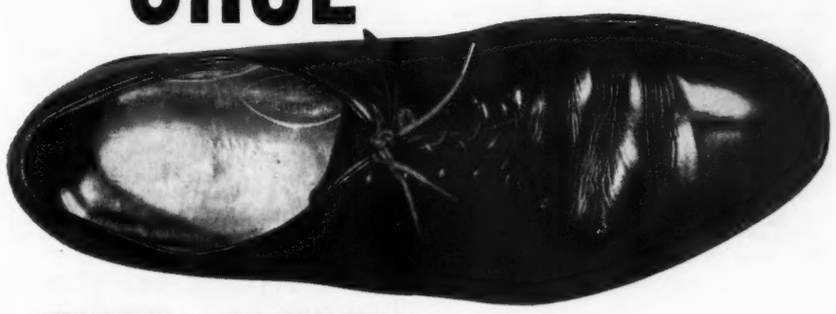
All-Epoxy Headers

An all-epoxy header, once available only as a part of an encapsulation system, is now being offered separately. Designed for use with either epoxy shells or conventional metal cases, the all-epoxy header could replace glass-to-metal hermetic seals in a wide variety of electronic applications. Since the header leads are embedded in cured, molded epoxy, there is no danger of cracked glass, no broken seals, no coefficient of expansion problem during the soldering operation. The virtual elimination of these problems results in a drastic reduction in assembly time and production rejects. In addition to conventional "straight through" leads, headers are available where the leads take a bend while passing through the body of the header. This enables the soldered ends of the lead to be in a different position on the header than the socket end of the lead. Dissimilar leads may be welded together and then molded into the body of the header for additional strength. Epoxy Products, Inc., Irvington, N.J.

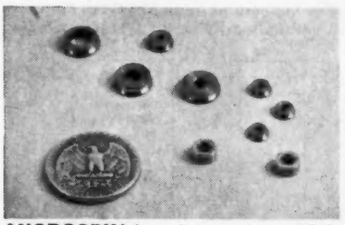
Circle No. 171 on Inquiry Card

Stop Overdesigning—

MAKE THE SHOE

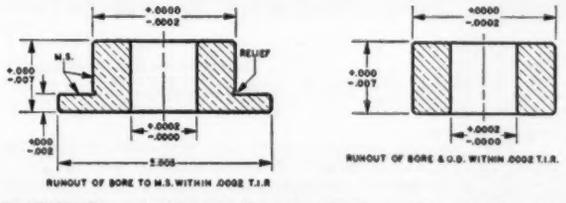


FIT THE FOOT!



MICROSPIN—Northfield's new miniature precision instrument bearings. Designed for a wide variety of applications where speed and torque requirements do not justify the high cost of expensive ball bearings, but where precision instrument standards of tolerances, life, and friction must be maintained.

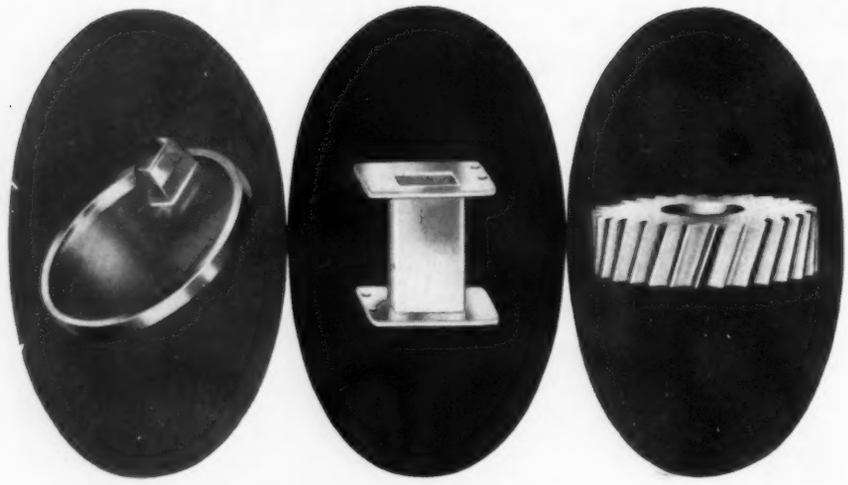
MICROSPIN bearings are precision-made of sintered bronze per MIL-B-5687, Type I, Comp. A, with 4% Molybdenum Disulphide. Oil-impregnated, completely self-lubricating. **Interchangeable with standard miniature ball bearings —at only ⅓ the cost! In stock—immediate delivery of production quantities!**



WRITE, PHONE for catalog-engineering data on standard and special sizes.
Northfield Precision Instrument Corp., Island Park, L. I., N. Y. GEneral 1-1112

NORTHFIELD
PRECISION INSTRUMENT CORPORATION

CIRCLE NO. 91 ON INQUIRY CARD



Experience and know-how behind each molded part

custom molders of the unusual

Even more important — to you — is its cost and quality. Our extensive 20-year background in the molding of plastics of all types assures you low-cost, high-speed production (with no loss of quality!) regardless of the size or quantity of your plastic needs. Your inquiries or problems will receive our prompt attention.

STANDARD PLASTICS CO., INC.

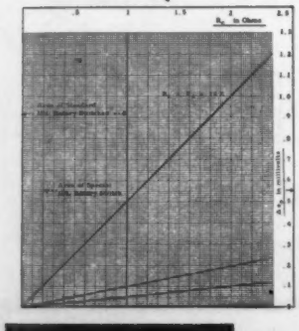
62 WATER ST. ATTLEBORO, MASS. Tel. AT. 1-4040 • N. Y. OFFICE: 303 FIFTH AVENUE Tel. MU. 6-0327

CIRCLE NO. 68 ON INQUIRY CARD

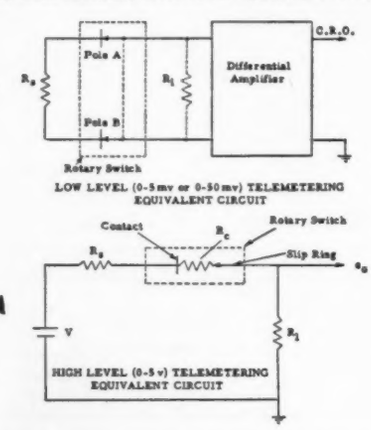
How Do YOU Define Switch Noise?

Here's how IDL analyzes it!

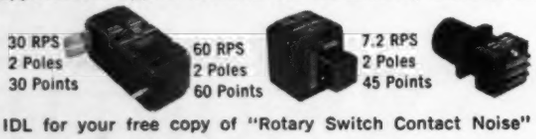
ROTARY SWITCH CONTACT NOISE



These data are important considerations in switch applications and provide you with valuable criteria for systems evaluation.



IDL quality control and inspection procedures insure that these "Standards of Excellence" are maintained in the production of high speed, sealed rotary switches for critical applications. Typical products are indicated by these units.



Write IDL for your free copy of "Rotary Switch Contact Noise"

INSTRUMENT DEVELOPMENT LABORATORIES, INC.

Subsidiary of Royal McBee Corporation

66 MECHANIC STREET, ATTLEBORO, MASSACHUSETTS, U.S.A.

CIRCLE NO. 69 ON INQUIRY CARD

Linear Actuators

Heavy-duty electrically-driven linear actuator for use in open-loop positioning has the precision ruggedness and reliability of aircraft and missile actuators. It moves up to three-quarters of a ton and can hold a ton-and-a-half. A brake reduces overcoast to a minimum. Significant advantage: self-contained unit requiring only line current for instant operation; fits into a sixteen-pound envelope. Lear, Inc., Grand Rapids, Mich.

Circle No. 108 on Inquiry Card

500°F Accelerometer

Featuring 500°F temperature operation and less than 3% cross-axis (lateral) sensitivity, a new self-generating accelerometer's first resonant frequency of 50KC widens the frequency range of vibration data that can be monitored. The unit's 1600 μμfd internal capacity reduces the effects of cable loss. The accelerometer's performance characteristics permits installation nearer to "hot spots," while protecting a companion pre-amplifier by installing it further away. Other features include maximum acceleration 500 g, hermetically sealed case (optional hermetically sealed cable and connector), high output for a given capsule size and accurate calibration for reliable repeat measurements. Clevite Electronic Components, Cleveland, Ohio.

Circle No. 257 on Inquiry Card

FHP Gearmotor

Sub-fractional horsepower worm drive gear motor offers quiet operation at low cost. The two pole, shaded a-c induction motor is available in voltages ranging from 6 to 220 volts, 50 or 60 cycle for continuous or intermittent operation. Output speeds from ½ to 300 rpm with output torque as high as 5 inch pounds at ½ rpm. Molon Motor & Oil Corp., Rolling Meadows, Ill.

Circle No. 109 on Inquiry Card

Plated Circuit Cards

Packaging flexibility is obtained with the use of a series of standardized plated circuit cards. Containing a standard grid pattern and hole spacing, the modules allow modification of standard sizes to fit individual applications. The cards have circuit contact extensions and a land pattern compatible with standard 0.1 grid design. U. S. Engineering Co., Van Nuys, Calif.

Circle No. 110 on Inquiry Card

Rotary Solenoids

Rotary solenoid is designed for the aircraft and missile industries requiring conformity with custom specifications and absolute accuracy under extreme environmental conditions. The new unit will function for millions of cycles, with no operating characteristic deterioration. The solenoid can be made to meet any required "torque to angle" relationship. The new design was made possible by an ingenious, reliable and compact converter added to a linear solenoid which translates the linear force into torque. This is accomplished by the use of roller bearings moving over precision cams to provide complete control of output torque characteristics. The output shaft has no linear motion. PSP, Div. of IMC Magnetics Corp., Westbury, L. I., N. Y.

Circle No. 253 on Inquiry Card

Linear Accelerometers

2 new additions to an accelerometer line are designed for low frequency acceleration measurement. A differential transformer linear accelerometer is a frictionless unit that has long-term stability and reliability. Featuring a self-contained oscillator-demodulator to accept dc input, the unit's output of 0-5 volts dc is linear with acceleration. The other unit is a potentiometer pick-off transducer that affords excellent resolution without sacrifice in frequency response. Both linear accelerometers can be hermetically sealed and are oil damped to eliminate the effects of random vibrations during measurement. Edcliff Instruments, Monrovia, Cal.

Circle No. 249 on Inquiry Card

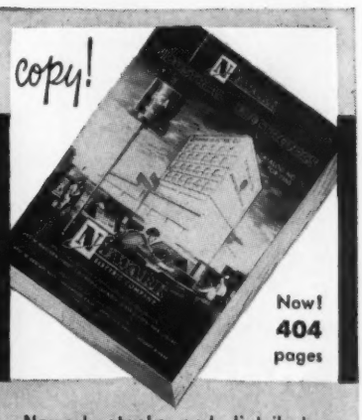
Miniature Synchronous Motor

Hysteresis synchronous motors of phase split capacitor type contain unique pole pieces and permanent magnet rotors. Outstanding features include: small and compact in size and light in weight; small electric power consumption and high torque (83.3 oz. in. per 50 rph. 115 v); reduction gear mechanism is closed type and designed so as to perform years of service without requiring lubrication; oil-less bearings for smooth and noiseless operation; direction rotation may readily be reserved only by the change of the external connection; all the component parts can be disassembled when repaired, even after a long use; temperature rise is small, and use of high grade lubricant makes it possible for performance in a wide range of temperature variation (−2 to 140°F). Yokogawa Electric Works, Inc., New York 13, N.Y.

Circle No. 170 on Inquiry Card

FREE! Write today for your copy!

NEWARK'S NEW All Industrial ELECTRONIC CATALOG NO. 70



Semi-Conductor Headquarters for Industry at Quantity Prices Competitive with Manufacturers

Audio Devices • CBS • General Transistor • General Instrument • General Electric • Hoffman • Hughes • Motorola • Philco • Raytheon • RCA • Sylvania • Ohmite • Sarkes Tarzian • Texas Instruments • International Rectifier

Newark stocks and distributes over 450 top lines covering every phase of electronics!

Semi-Conductors • Connectors • Relays • Switches • Industrial Tubes • Test Equipment • Transformers • Controls • Resistors • Meters • Capacitors • Pilot Light Assemblies

Your One-Point Source for All Your Electronic Needs

NEWARK ELECTRONICS CORPORATION
Formerly NEWARK ELECTRIC CO.
Dept. EL-4, 223 West Madison Street, Chicago 6, Illinois
Dept. EL-4, 4747 West Century Blvd., Inglewood, California

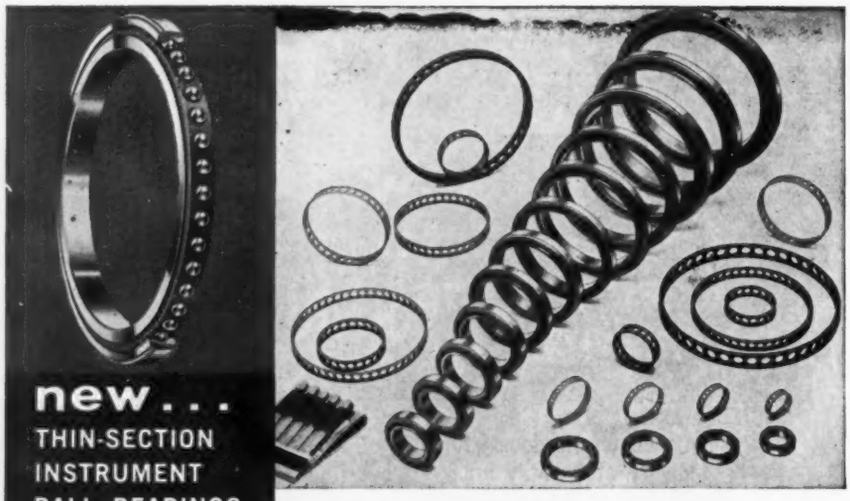
• COMPETITIVE FACTORY PRICES
• COMPLETE ON-HAND STOCK
• IMMEDIATE DELIVERY

CIRCLE NO. 70 ON INQUIRY CARD

MINIATURIZATION

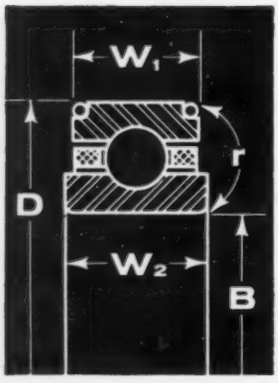
We are far into new areas with miniaturized and microminiaturized electromagnetic devices used in the Inertial Guidance systems we build. Our staff openings in miniaturization are for men who think big. Write to Mr. C. T. Petrie, Manager, Research & Engineering Staff.

LITTON INDUSTRIES Electronic Equipments Division
Beverly Hills, California



PRECISION AND ULTRA-PRECISION GRADES

TYPE TCR MAXIMUM BALL COMPLEMENT WITH ONE-PIECE RETAINER



The type TCR bearing offers the maximum radial and thrust capacity possible in a retainer-type ball bearing of these dimensions, and considerably more capacity than a conventional thin-section bearing with a two-piece retainer or spring separators. There are no filling notches and thrust capacity is two-directional.

Type TCR bearings are used for optimum performance — high speeds, high loads, and low torque. Only with the SBB design is it possible to have a maximum ball complement with a one-piece retainer, and keep the advantages of continuous race shoulders. The one-piece retainer is strong and light, precision-machined from reinforced phenolic.

Available with full ball complement (without retainer) as types TCF and TCA.

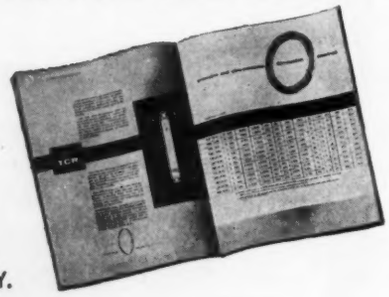
number	*B bore	*D o.d.	W_1 +.000 −.005	W_2 +.000 −.005	Balls no.	Balls size	wt. lbs.	‡L lbs.	§S lbs.
TCR 10-17	.6250	1.0625	.250	.281	18	7/64	.032	228	370
TCR 12-19	.7500	1.1875	.250	.281	18	1/8	.037	280	490
TCR 14-21	.8750	1.3125	.250	.281	20	1/8	.042	310	540
TCR 17-24	1.0625	1.5000	.250	.281	24	1/8	.05	360	650
TCR 21-28	1.3125	1.7500	.250	.281	28	1/8	.06	370	760
TCR 25-32	1.5625	2.0000	.250	.281	34	1/8	.07	390	925
TCR 29-36	1.8125	2.2500	.250	.281	38	1/8	.08	410	1030
TCR 33-42	2.0625	2.6250	.250	.281	44	1/8	.12	435	1200
TCR 37-46	2.3125	2.8750	.250	.281	48	1/8	.13	450	1300
TCR 41-52	2.5625	3.2500	.312	.375	36	3/16	.22	835	2200
TCR 45-56	2.8125	3.5000	.312	.375	39	3/16	.24	850	2370
TCR 49-62	3.0625	3.8750	.312	.375	42	3/16	.26	880	2550

Dimensions are in inches. Balls and rings of 52100 high chrome alloy bearing steel. Also available in 440 C stainless. Radius "r" will clear .015" shaft or housing fillet. *Tolerances vary according to size — see catalog 59 for Precision Grade and Ultra-Precision Grade Tolerances. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-brinell load capacity.

send for new catalog 59

Split's catalog 59 provides complete coverage on the complete T series of thin-section precision instrument ball bearings. No designer should be without it.

WRITE FOR YOUR COPY TODAY.



split ballbearing
A DIVISION OF MPB, INC.
522 HIGHWAY FOUR, LEBANON, NEW HAMPSHIRE

CIRCLE NO. 71 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Trimmer Potentiometer

A 25 turn trimmer potentiometer ha complete welded construction of a fixed connections and sealed constru tion for maximum protection fro severe environmental conditions. Rate at 1 watt to 90°C it has an operati temperature range of −65 to 165° with 17 standard resistance value ranging from 10 ohms to 50 K ohms Standard tolerance is 5 percent. Del Products, Inc., Columbus, Nebraska.

Circle No. 161 on Inquiry Card

Two Speed Blowers

The unique design of the exhaust are of a blower permits greater air turbu lence over the entire rack interior. Thi accomplishes faster and more efficie dissipation of heat around tubes, semi conductors, crystals and other sensitiv components. The unit is a 19 inch, 50 cfm centrifugal blower that pressuriz a cabinet with clean cool filtered air Recessed design permits maximum us of panel area. Various rack depths are available. McLean Engineering Labs. Princeton, N. J.

Circle No. 251 on Inquiry Card

Coaxial Terminations

Deliberately mismatched terminations present a constant, known value o vswr to a 50 ohm line over an extended frequency range, to facilitate rapi calibration of vswr measuring equip ments. N, BNC and TNC connector types cover 0-3 KMC and LT con nector types cover 0-1.5 kmc. Standard vswr values are 1.5, 2.0, 2.5, 3.0 Radar Design Corp., Syracuse, New York.

Circle No. 96 on Inquiry Card

Smaller Size 8 Servo Motor

Designed for smaller space applica tions, a size 8 servo motor measures only 0.863" long, weighs 1.2 oz. and has a −55° C to +125° C ambient temperature range. Stall torque is 0.1 oz. in., no load speed 6200 rpm at rated voltages of 26v fixed phase and 40v control phase, rotor inertia 0.0 gm.cm² and T.1 ratio 30,000 rad/sec² Impedances are 230 = 190 + j131 for 26v winding and 519 = 399 + 332 j 40v winding. John Oster Mfg. Co., Ra cine, Wisconsin.

Circle No. 131 on Inquiry Card

E-W Custom Cooling

Condition: Unusual Configuration

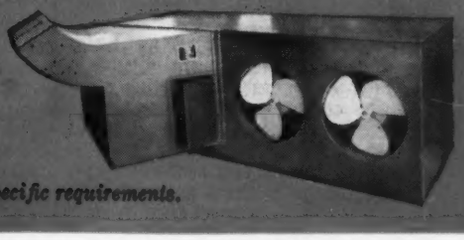
Today's electronic systems invariably require specialized cooling equipment that is compact, lightweight, fits into unusual configurations, and still meets the most difficult environmental conditions (MIL-E-4970*).

Custom air-conditioning is our business at Ellis and Watts. For example, our MIL-AC air conditioning units can be square, oblong, L-shaped, T-shaped, curved, pyramid—virtually any shape your conditions require. They can be designed for integral mounting in electronic consoles or computer racks; or for use as adjacent or remote equipment to air condition entire systems.

MIL-AC units are self-contained, compact, lightweight, readily air-transportable. They can be designed to cool, heat, humidify, dehumidify, filter, and can incorporate air-cooled or water-cooled condensers. Units are manually or automatically controlled. We are staffed with specialists who will analyze your requirements, submit a proposal, complete your installation promptly and to your complete satisfaction.

Write for helpful load calculating Nomograph and other technical data for use in making time-saving preliminary calculations.

*Military specification dealing with the following climatic and environmental conditions: Temperature, humidity, altitude, salt spray, vibration, fungus, sunshine, rain, sand and dust, explosive atmosphere, acceleration and shock



Typical MIL-AC *Unit.* MIL-AC *configurations, features and functions to suit your specific requirements.*

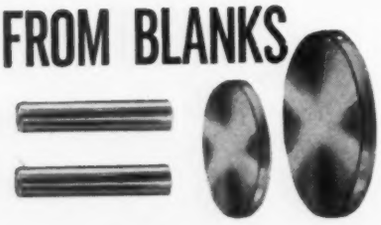
ELLIS AND WATTS PRODUCTS, INC.

P.O. Box 33M, Cincinnati 36, Ohio

Ellis and Watts also design and build custom air conditioners, liquid coolers and heaters, dehumidifiers, wave guide dehumidifiers, laboratory temperature and humidity control units.

CIRCLE NO. 72 ON INQUIRY CARD

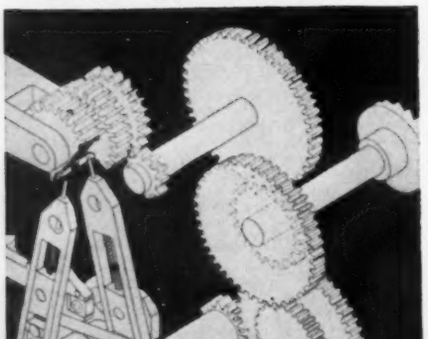
FROM BLANKS



TO GEARS

H. O. Boehme, Inc. is unsurpassed as a facility for the production of quality precision products. Over 3 decades of experience on specialized precision work in the fields of Instrumentation and Automation has provided us with the rare discipline required to produce custom-made fine pitch precision gears to A.G.M.A. Precision #3 specifications and the closest of tolerances. Our engineering staff is progressive, our craftsmen are highly skilled and experienced, our facilities include the latest, accurate fabrication and testing equipment.

TO ASSEMBLIES



The Boehme gear assembly shown here demands perfect timing between gear elements, a relationship that can only be obtained by gears of perfect true form.

Modern industrial techniques and a rigorous quality control system enables us to offer you high precision products to meet your exacting specifications and tolerances, and at the same time to keep production costs within budgetary limitations. Whatever your need—design, engineering, precision products, custom-made gears and assemblies—in small quantity or in production runs—your inquiries are invited. There is no obligation, of course.

H. O. Boehme, Inc.

Contractors, Designers, Manufacturers of Precision Electrical, Electro-Mechanical and Electronic Equipment since 1917

915 Broadway
New York 10, N.Y.

HOB

CIRCLE NO. 74 ON INQUIRY CARD

New Electronic Components For Electromechanical Systems

Encapsulated Servo Amplifier

Having its own d-c power supply and preamplifier built into an encapsulated unit, a servo amplifier is about the size of a cigarette package. It requires a power input of either 26 or 115 volts, 400 cycles rms. Output is either 13 or 26 volts rms at 2.5 watts, and is designed to drive a size 8 servo motor. Silicon transistors in the preamplifier section drive a fast response magnetic amplifier output stage to control the motor. A damping current is generated in the unit under all signal conditions such that, for many applications, a rate feedback is required. Because of it encapsulated construction, it exhibits excellent stability characteristics and a high degree of resistance to environmental conditions. Cedar Engineering Div., Minneapolis, Minn.

Circle No. 159 on Inquiry Card

Microwave Diodes

Two new broadband video detector microwave diodes are said to be the first in the industry to cover the 10 to 20 kmc frequency band. Type D-4104 has a minimum tangential signal sensitivity of minus 40 dbm and a minimum figure of merit of 15. Type D-4104A has a minimum sensitivity of minus 45 dbm and a minimum figure of merit of 30. Both diodes use a non-tripolar coaxial package and have a maximum video impedance of 18,000 ohms. Sylvania Electric Prods., Inc., Semiconductor Div., Woburn, Mass.

Circle No. 254 on Inquiry Card

Current Sampling Transformer

Low voltage pulses with the same shape as the high current pulses, are frequently required for synchronizing purposes in other portions of a system. Bulky resistive networks to develop the low voltage pulses can be eliminated by using an inexpensive, miniature, light weight transformer. The low level transformer can be used with currents in the order of 175 amps because the transformer is not connected to the current carrying conductor; the conductor is simply passed through a hole in the transformer. Valor Instruments, Inc., Gardena, Cal.

Circle No. 255 on Inquiry Card

Mesa Transistors

Silicon mesa power transistors are capable of delivering one watt power output at 70 mc with a 28 volt collector voltage. The two new types are characterized by 3 watt collector dissipation, 40v collector to emiter rating and low collector capacitance. The units are particularly well suited where severe environmental conditions are encountered. Pacific Semiconductors, Inc., Culver City, Cal.

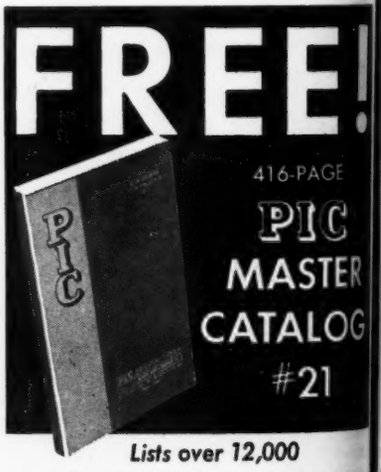
Circle No. 247 on Inquiry Card

Miniature Chopper

The outstanding feature of a Synchroverter chopper is an 83° nominal phase lag (at 400 cps) which eliminates space-consuming phasing networks. The new chopper is of basic non-resonant design, and exhibits high reliability and shock and vibration resistance. Size of the unit is 1⅝ inch x ⅝ inch. The Bristol Co., Waterbury, Conn.

Circle No. 250 on Inquiry Card

FREE!



416-PAGE
PIC MASTER CATALOG #21

Lists over 12,000
PRECISION INSTRUMENT PARTS and ASSOCIATED COMPONENTS
Available From STOCK!

GEARS • SHAFTS • COLLARS • CLUTCHES • BEARINGS • COUPLINGS • DIFFERENTIALS • SPEED REDUCERS and many other Precision Engineered Parts & Components.

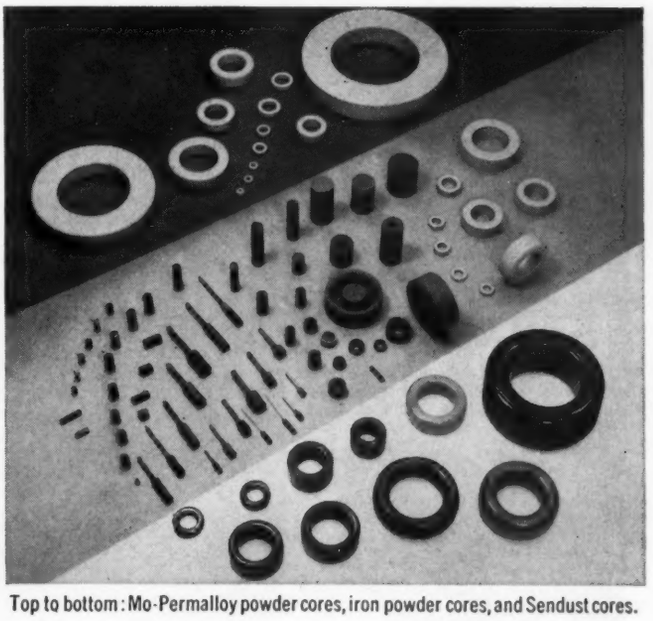
Send For Your Copy Today.

PIC DESIGN CORP.
Subsidiary of BENRUS WATCH COMPANY, Inc.
477 Atlantic Ave., East Rockaway, L.I., N.Y.

CIRCLE NO. 73 ON INQUIRY CARD

Specify "ARNOLD"
for your MAGNETIC CORE requirements

Top to bottom: Tape wound cores, Silectron C, E and O cores, and bobbin cores.



Top to bottom: Mo-Permalloy powder cores, iron powder cores, and Sendust cores.

SILECTRON C-CORES, E-CORES and TOROIDS Arnold C and E cores are made from precision-rolled Silectron strip in 1, 2, 4 and 12 mil thicknesses.

They are supplied in a wide variety of shapes, and in sizes from a fraction of an ounce to several hundred pounds. In addition to standard transformer applications, they may also be supplied for special applications such as saturable reactors, instrument transformers and pulse transformers.

Over 1,000 stock cores are listed in the Arnold Silectron catalog. A wide selection of preferred sizes are carried in stock for immediate shipment. For complete data on C and E cores and Silectron toroids, *write for Bulletin SC-107A.*

TAPE WOUND CORES of High Permeability Materials Arnold tape wound cores are available made of Deltamax, 4-79 Mo-Permalloy, Supermalloy, Mumetal, 4750 Electrical Metal, Silectron, or the new rectangular-loop material, Supermendur. All except Supermendur cores are available in standard tape thicknesses of 1, 2 and 4 mils; also in special tape thicknesses of ½ mil, 12 mil or other, as required or feasible. Supermendur is presently available in 4 mil cores.

Toroidal cores are made in 30 standard sizes with protective nylon or aluminum cases. Special sizes of toroidal cores are produced to individual requirements. *Write for Bulletin TC-101A. (TC-113A for Supermendur Cores.)*

BOBBIN CORES Arnold bobbin cores are available in a wide range of sizes, tape thicknesses, widths and number of wraps to suit the ultimate use of the core in electronic computer assemblies. Magnetic materials usually employed are Deltamax and Square Permalloy in standard thicknesses of 1, ½, ¼ and ⅛ mil. Bobbins are supplied in ceramic or stainless steel. *Write for Bulletin TC-108A.*

MO-PERMALLOY POWDER CORES Available in a wide range of sizes, from .260" OD to 5.218" OD. They are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.

These powder cores are supplied in four standard permeabilities: 125, 60, 26 and 14 Mu. They provide constant permeability over a wide range of flux density, and in many cases may be furnished stabilized to provide essentially constant permeability over a specific temperature range. Large warehouse stocks of preferred sizes are carried for immediate shipment. *Write for Bulletin PC-104C.*

IRON POWDER CORES A wide selection of cores is available, from simple cylinders to special cores of complicated design. The line includes all standard types of threaded cores, cup, sleeve, slug and cylindrical insert cores: for use in antenna and RF coils, oscillator coils, IF coils, perm tuning, FM coils, television coils, noise filter coils, induction heating and bombarder coils, and other low frequency applications. Preferred sizes are carried in warehouse stock for quick shipment. A standard series of iron powder toroids is also manufactured, conforming to the standard sizes proposed by the Metal Powder Industries. *Write for Bulletin PC-109.*

SENDUST POWDER CORES Available in a wide selection of sizes, ranging from .800" OD to 3.346" OD, and in permeabilities of 10, 13, 25, 30, 50 and 80, although not all sizes are available in all permeabilities. They possess magnetic properties generally superior to iron powder cores, but inferior to Mo-Permalloy powder cores in the audio and carrier frequency range. *Write for Bulletin SDC-110.*

SPECIAL MATERIALS

2V PERMENDUR . . . a ferromagnetic alloy of cobalt, vanadium and iron that possesses high flux density saturation properties. Its magnetostrictive properties are useful in many transducer applications. *Write for Bulletin EM-23.*

VIRALLOY . . . a ferromagnetic alloy of nickel, molybdenum and iron whose temperature coefficient of elastic modulus is controllable over a wide range. It has high ferromagnetic permeability, and a rather high coefficient of magnetostriction. Used in applications where a zero or controlled thermo-elastic coefficient is desired.

BARIUM TITANATE . . . A piezoelectric ceramic widely used in accelerometers, phono pickups, microphones, ultrasonic grinding and cleaning devices and underwater signaling devices. For more information, *write for Bulletin CM-116.*

7507 C

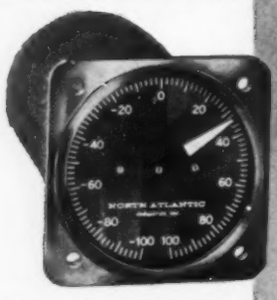
ARNOLD

SPECIALISTS in MAGNETIC MATERIALS

THE ARNOLD ENGINEERING COMPANY, Main Office: MARENGO, ILL.
BRANCH OFFICES and REPRESENTATIVES in PRINCIPAL CITIES

CIRCLE NO. 75 ON INQUIRY CARD

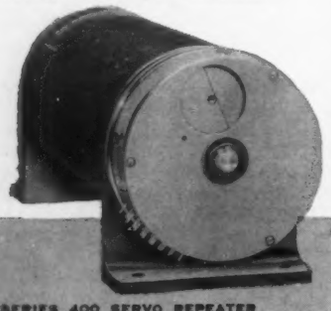
Servo Instrumentation for DATA CONVERSION



SERIES 200 SINGLE POINTER INDICATOR
For applications requiring accuracies and resolutions of less than .2% and high speed of response.

SERIES 200 DUAL POINTER INDICATOR
For high resolution and accuracy application where readability and dynamic response are important.

SERIES 300 DIGITAL DISPLAY INDICATOR
For highest accuracy and resolution.



SERIES 400 SERVO REPEATER
For general purpose repeater and digitizer applications where visual readout is not required.

A complete line of precision, high performance Servo Data Conversion Equipment designed to accommodate any input and output requirement.

Available as

SERVO READOUT SYSTEMS

RATIOMETERS

TEMPERATURE MEASURING SYSTEMS

MILIVOLTMETERS

SERVO DATA CONVERTER

A TO D SERVO CONVERSION SYSTEMS

Write for complete technical data and application information.

NORTH ATLANTIC *industries, inc.*
603 main street, westbury, n.y. EDgewood 4-1122

CIRCLE NO. 76 ON INQUIRY CARD

ELECTRONIC COMPONENTS

Single Phase Inverter

A new single phase inverter designed specifically to supply accurate 400 cycle power to rate gyro packages is suitable for any application requiring small quantities of 26±1.0% volt 400 power. Occupying only 20 cubic inches, this unit is capable of delivering 20 watts at 400 cycles ±0.1% with an input voltage of 28±4 volts. Distortion is less than 4%. Efficiency exceeds 60% at full load. Temco Aircraft Corp., Dallas, Texas.

Circle No. 129 on Inquiry Card

Silicon Power Rectifiers

Rated at 13 amps average at 25°C Ambient on a 3″ x 3″ x 1/6″ copper heat sink, a silicon power rectifier achieves standard and reserve polarity through double diffusion. Typical forward dynamic resistance is .009 ohm. Syntron Co., Hower City, Pennsylvania.

Circle No. 97 on Inquiry Card

Silicon Transistors

Power dissipation of 125 watts at 25°C case temperature; 50 mc alpha cut off frequency; 10 amps continuous collector current and 0.2 ohm saturation resistance characterize two models of diffused mesa transistors. Pacific Semiconductors, Inc., Culver City, Cal.

Circle No. 98 on Inquiry Card

Silicon Power Rectifiers

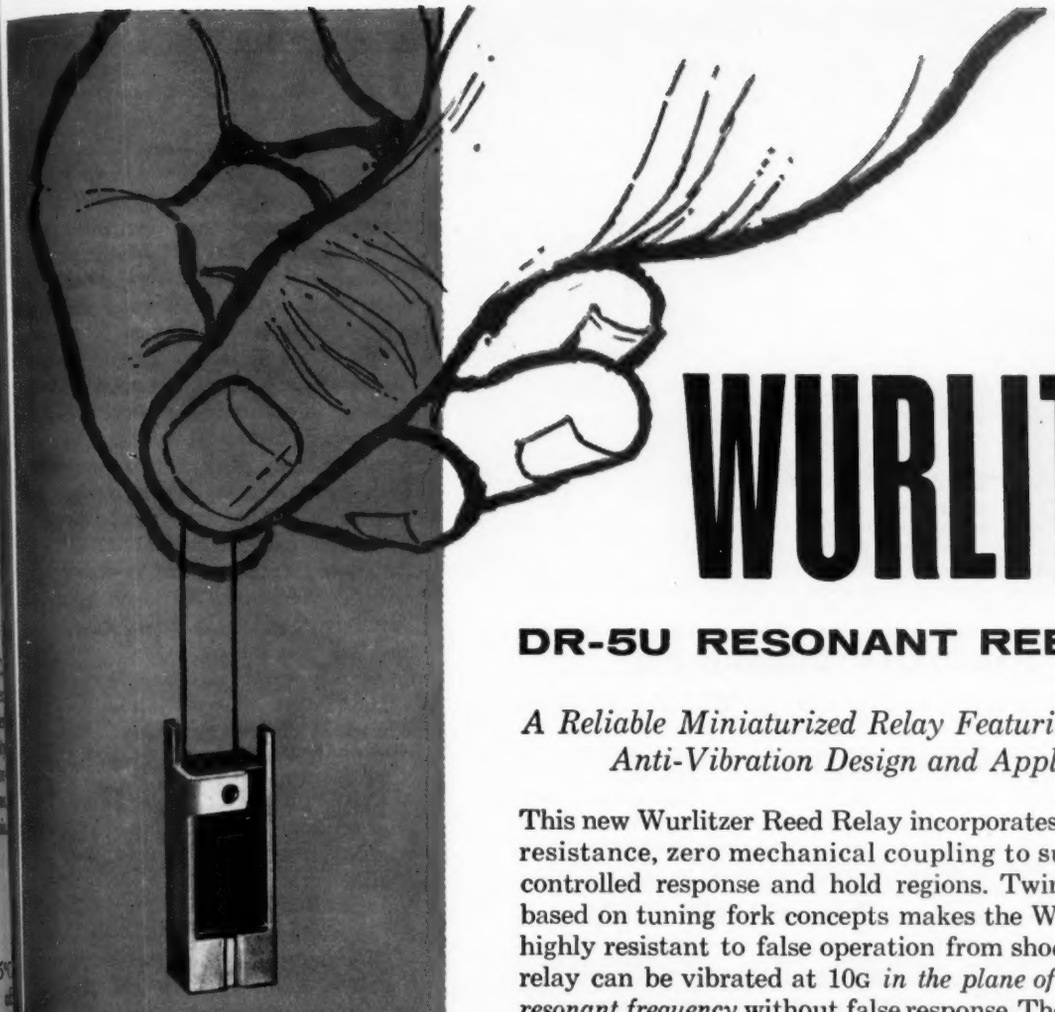
Featuring a high reverse voltage characteristic ranging from 200 to 600 vdc, new military type silicon power rectifiers will operate at high temperatures with the low reverse current of one milliampere at 150°C. The new rectifiers are characterized by low forward voltage drop of 1.5 vdc at 10 adc. Bendix Semiconductor, Long Branch, N.

Circle No. 252 on Inquiry Card

Transistorized Digital Modules

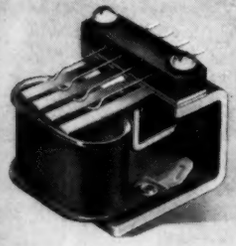
Used to assemble digital systems without designing circuits, compatible modules include flip flops, shift registers, multivibrators, one shots, delay logic and many others. There are neon indicators on flip flops and shift registers and allowance for remote indicator. Control Equipment Corp., Needham Heights, Mass.

Circle No. 99 on Inquiry Card



Uncased Resonant Reed Relay

Hermetically Sealed Resonant Reed Relay



Multiple frequency reed relay for Commercial Applications

WURLITZER

DR-5U RESONANT REED RELAY

A Reliable Miniaturized Relay Featuring Anti-Vibration Design and Application Flexibility

This new Wurlitzer Reed Relay incorporates shock and vibration resistance, zero mechanical coupling to support, and closely controlled response and hold regions. Twin reed configuration based on tuning fork concepts makes the Wurlitzer Reed Relay highly resistant to false operation from shock or vibration. The relay can be vibrated at 10G *in the plane of the vibrating reed at resonant frequency* without false response. The response frequency is not affected by changes in mass, rigidity, or plane of mounting.

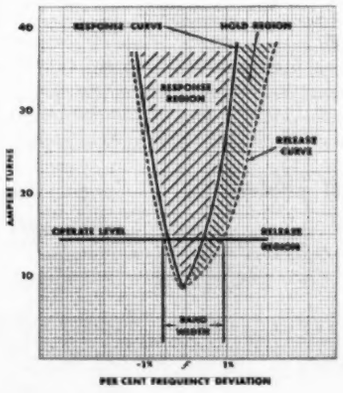
The release curve is nearly coincident with the response curve, allowing closer spacing of operating frequencies thus providing more channels for a given spectrum and reduced bandwidth. Its frequency variation is less than 0.5% from −60°F to +150°F.

Has application in:

- Frequency Sensing and Measurement
- Selective Tone Communication and Control Systems
- Frequency Generation
- Controlled Sequence Contacting Applications

SIZE 1-3/32" x 7/16" x 7/16" — WEIGHT 10.7 Grams

Available in uncased, hermetically sealed, and plug-in models for frequency range of 300 to 1000 cps. Other frequencies available.



Inquiries Invited

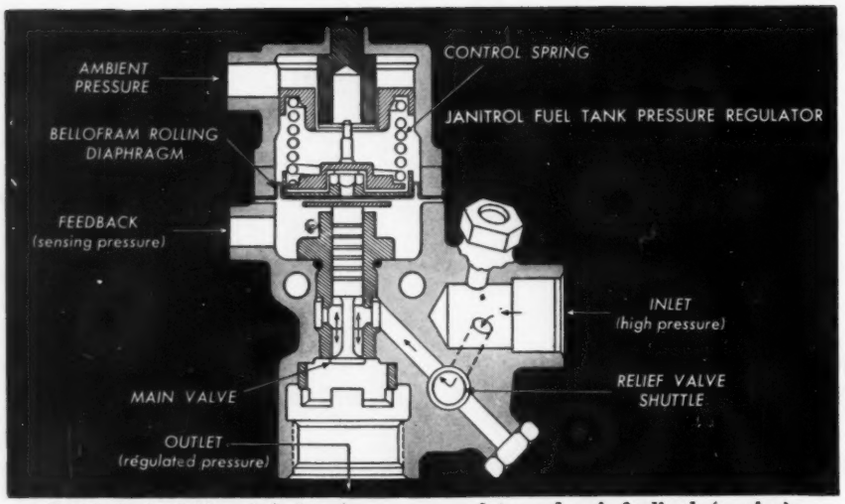
ELECTRONICS AND DEFENSE PRODUCTS DIVISION

THE WURLITZER COMPANY

NORTH TONAWANDA, N. Y.

WURLITZER Research Engineering Production

CIRCLE NO. 77 ON INQUIRY CARD



In this Janitrol Aircraft fuel-tank pressure regulator, a drop in feedback (sensing) pressure allows combined force of ambient pressure and control spring to increase opening of main flow valve until system is again balanced in terms of ambient pressure. If ambient pressure drops with altitude, causing imbalance due to increased feedback pressure, frictionless Bellofram Rolling Diaphragm responds instantly to close valve. Write for free literature.

Fuel-Tank Pressure Stabilized With Frictionless Rolling Diaphragm

PROBLEM To design a pressure regulator capable of stabilizing fuel-tank pressures in aircraft and missiles despite the following variables: (1) Altitude variations from sea level to 70,000 feet. (2) Compressor bleed air pressures from 12 to 250 psig. (3) Compressor bleed air temperatures from −65°F to +350°F.

SOLUTION Janitrol Aircraft designers concluded that the key to their problem was to find a diaphragm or bellows of compact configuration that would respond instantly to minute variations in pressures. In addition, this device would have to be absolutely leakproof, vibration-proof, immune to aviation fuels and their vapors, and—most important—as friction-free as possible for maximum sensitivity.

The only seal that met *all* these specs was a Bellofram Rolling Diaphragm, which for this application consisted of a high-strength fabric overlay impregnated with a special fluorinated silicone elastomer. In addition to sensitive, trouble-free performance at the prescribed pressures and temperatures, the use of this diaphragm resulted in lower manufacturing cost, for this reason:

Because of the unique *rolling* action of the Bellofram Diaphragm, efficient performance of the regulator does not depend upon close-tolerance machining of the mating piston and cylinder. Hence substantial economies were achieved in the finish, material, and hardness of these heretofore critical parts.

WHAT ARE YOUR SPECS?

If conventional bellows, O-rings, and cup packings do not meet your requirements for use in actuators, pumps, instruments, seals, accumulators, fluid dampers, etc., consider these *additional* advantages of Bellofram Rolling Diaphragms:

They provide frictionless response with positive action in small configurations and can be produced in materials compatible with almost any environmental gas or fluid.

They have no break-out friction or spring gradient effects, and have low hysteresis characteristics. Flex life is often measurable in millions of cycles, and de-icing action is automatic. Over 100 stock sizes are available.

OPERATING LIMITS

Operating Pressures: 1 inch H_2O to +500 psi (up to 1200 psi in some cases).
Operating Temperatures: −85°F. to +550°F. (from −120°F. to +700°F. in some cases).
Cylinder Bore Sizes: .25 to 12 inches.
Effective Pressure Area: .028 to 108 sq. in.
Total Stroke Capabilities: .01 to 12 inches.
Sidewall Thickness: .008 to .035 inches.

nothing rolls like a

Bellofram®

rolling diaphragm

BELLOFRAM CORPORATION, 18 BLANCHARD RD., BURLINGTON, MASS.
BRowning 2-2100 Mission 3-9000

®Reg. trademark U.S.A. and foreign countries • Bellofram Rolling Diaphragms are protected by U.S.A. and foreign patents.

ELECTRONIC COMPONENTS

Silicon Transistors

Four new high frequency NPN silicon transistors have a minimum alpha cut-off frequency rating of 15-megacycles. A unique mounting design, in which a fragile silicon pellet is mounted on a ceramic disk which in turn is mounted to the floor of the transistor housing, allows the finished transistor to far exceed rugged military, mechanical environmental specs. Typical output capacity rating is 2 micro-microfarads with the maximum ratings at 5 micro-microfarads. The temperature range of the transistors is from 65°C to +200°C. General Electric Company, Schenectady, N. Y.

Circle No. 238 on Inquiry Card

Compact Transistorized Power Supply

A well regulated dc power supply contains voltage and current meters for accurate setting of output voltage and continuous monitoring of load currents. Voltage output is adjustable from 5 to 35 volts with a maximum current of 2 amperes. Either the positive or negative terminal may be grounded or the output can be floating. Regulation is better than 0.1% and variation in output voltage is never more than 30 millivolts. Ripple is held down to less than 1 millivolt. The unit weighs approximately 14 lbs and occupies less than a square foot of space. Protection against load short-circuit is provided by a fast circuit breaker with manual reset. Solidyne, La Jolla, Cal.

Circle No. 134 on Inquiry Card

Static Inverter

Static inverters designed for application in aircraft, missiles, satellites, and ground guidance and detection systems is a precision dc-ac power converter designed to operate from a nominal 28 VDC source and to provide 26 V 400 cps 3 ϕ power at 20 VA per phase for a total of 60 VA. Solid state components are used throughout. The unit is highly stable in frequency, phase and voltage, and will operate at base plate temperatures to +100C. It incorporates: automatic voltage regulation ±5% no load to full load, short circuit protection-with automatic recovery, and reverse voltage protection. Magnetic Amplifiers, Inc., N.Y., N.Y.

Circle No. 155 on Inquiry Card.

Frequency Meters

A new series of suppressed range frequency meters were designed to fill the gap between simple field units and elaborate laboratory standards. The manufacturer claims that the new meters are rugged enough for the most severe field use yet are precise enough to be used as secondary standards. The meters consist of a converter, which translates input frequencies into direct current signals, and a separate indicator, which uses the output from the converter to indicate corresponding frequencies on a linear scale. There are no moving parts in the magnetic-amplifier-type converter, all internal components—toroids, diodes, resistors and capacitors being static. Input to the meter is 105 to 135 volts AC of the frequency being measured; no auxiliary power is required. Accuracy of the meter is the sum of 2.5% of the frequency range and 0.25% of the frequency being measured, over a temperature range of −65 to +130°F. This includes 2% for possible indicator error. Separate temperature compensation of converter and indicator permits remote location of converter to conserve panel space and to allow minimum panel depth. Consolidated Controls Corp., Bethel, Conn.

Circle No. 187 on Inquiry Card

Compact Frequency Standard

A compact precision frequency standard provides a stability of $5/10^8$ parts per week and $3/10^8$ over short intervals. Signals available include six sinusoidal frequencies (10 cps, 100 cps, 1 KC, 10 KC, 100 KC and 1 MC) and four pulse signals (10 cps, 100 cps, 1 KC and 10 KC). The frequency standard includes a timing comb for calibrating, and measurement of sweeps and time intervals. The instrument is extremely compact; 8¾" high, 19" wide and 18" deep and weighs 35 lbs. Hewlett-Packard Co., Palo Alto, Cal.

Circle No. 190 on Inquiry Card

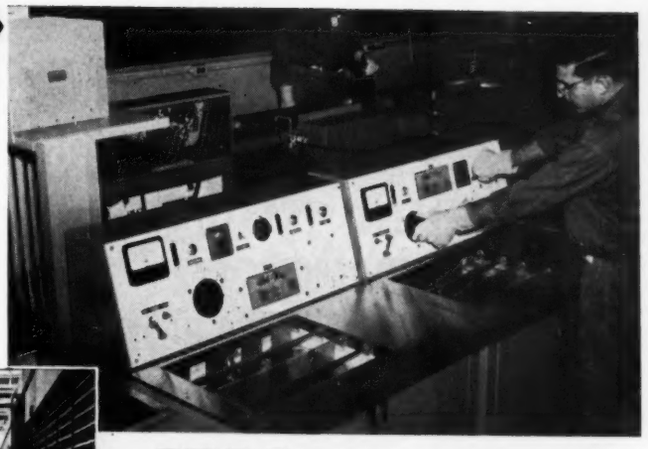
Miniature Temperature Sensor

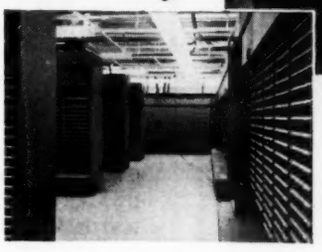
Temperature sensing device ¼" x ⅛" is a completely sealed and potted resistance temperature sensor. The unit changes resistance at a rate of 0.393% for each degree Fahrenheit change in temperature, yet its tolerance over a wide temperature range is 0.1%. Two leads conduct signals from the potted unit to indicator equipment. Dale Products, Inc., Columbus, Nebraska.

Circle No. 177 on Inquiry Card

These JET PLATERS are used to gold-plate some of the printed wiring boards for the SAGE Computer — as well as for experimental IBM equipment currently under development.

Heart of our SAGE System is the 275 ton IBM Computer. Shown here are some of the computer frames containing pluggable electronic units which perform data processing to solve air-defense problems.



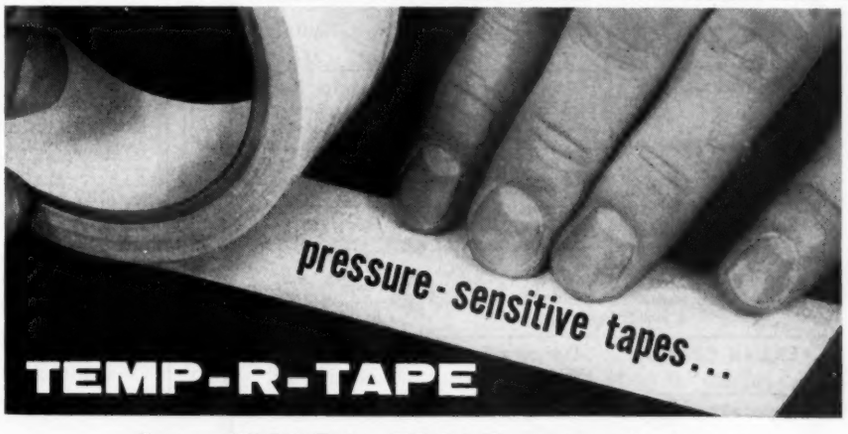


IBM SAGE COMPUTER CIRCUITRY PLATED WITH SEL-REX BRIGHT GOLD

The 275 ton computer pictured, in part, above has 7,300 pluggable units containing printed card assemblies. To help maintain the "built in" reliability for which I B M is famous the world over, these assemblies were plated with Sel-Rex Bright Gold Process. The precision-plating required by this application was done in four JET PLATERS—complete precious metal plating facilities in a single compact cabinet.

When the unique metallurgical properties of a precious metal are required—*without the shortcomings of conventional electroplate*—leading missile, electronic manufacturers and Government Agencies specify SEL-REX. Learn why from our latest catalog #EL-1, FREE on request.

Sel-Rex® SEL-REX CORPORATION
NUTLEY 10, NEW JERSEY
CIRCLE NO. 78 ON INQUIRY CARD



for −100° F to 500° F applications

Select the right Temp-R-Tape for your job from a variety of types which combine some form of Teflon, Fiberglas or Silicone Rubber backing with a silicone polymer adhesive. Temp-R-Tapes possess high dielectric strength, thermal stability, excellent moisture resistance, non-aging characteristics and many other desirable properties.

CLASS H INSULATION USES: slot lining; interlayer and interphase insulation; harness bundling; splicing; wrapping for microwave components, transformer coils, capacitors and high voltage cables.

NON-STICK USES: non-stick facings for film guides in electronic instruments, heat sealing bars, forming dies, chutes, guide rails, etc.

AVAILABLE FROM STOCK: 1/4" to 2" widths, 18 yd. and 36 yd. rolls and 12" width on liner by lineal yard. Sold through distributors.

FREE SAMPLE and folder — write, phone or use inquiry service.

ELECTRICAL AND INDUSTRIAL SPECIALTY TAPES

CHR **CONNECTICUT HARD RUBBER CO.**
*duPont TM
Main office: New Haven 9, Connecticut
CIRCLE NO. 79 ON INQUIRY CARD

Sensitive DIFFERENTIAL PRESSURE and VACUUM CONTROLS

J6K J27KB

By using **UNITED ELECTRIC's** Type J6K or Type J27KB control, it is possible to control accurately the difference in pressure between two pressure or vacuum sources. The J6K contains a single switch; the J27KB is a dual switch control.

System Differential	Up to 90 psi.
Switch Differential	J6K — can be set between limits of ½" Hg and 3 psi. J27KB — can be set between limits of 1" Hg and 5 psi.
Switch Ratings	15 amps. at 115 or 230 volts A.C. Also 20 amps. or D.C. switches on specification.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
Adjustments	J6K — internally located, uncalibrated adjustment wheel. J27KB — each switch has independent, uncalibrated adjustment screw.
Electrical Connections	Made to screw terminals on switches through clearance hole in enclosure.
Pressure Connections	Two ¼" female NPT pressure connections.
Size	J6K — 7 5/32" x 4 27/32" x 2 5/16". J27KB — 7 1/16" x 6 1/8" x 2 7/8".
Approximate Weight	J6K — 2¼ lbs. J27KB — 2 lbs.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure and vacuum controls. Standard units can be modified or custom-built units made to your specifications. Additional information on pressure and vacuum controls is available upon request.*

U.E.® United Electric Controls COMPANY
91 SCHOOL STREET, WATERTOWN, MASS

CIRCLE NO. 80 ON INQUIRY CARD

ADVERTISERS' INDEX

ADVERTISERS	Page Number
Acromag, Inc.	78
American Electronics, Inc.	15
Amphenol-Borg Electronics Corp. (Borg Equipment Div.)	60
Arnold Engineering Co., The	85
Associated Spring Corp.	7
Atlas Precision Products Co.	64
Automatic Electric Co.	2
B & H Instrument Co., Inc.	54
Bellofram Corp.	88
Bird, Richard H., & Co.	31
Boehme, H. O., Inc.	84
Bowmar Instrument Corp.	16
Bristol Co., The	68
Carter Motor Co.	77
Centralab (The Electronics Div. Globe-Union, Inc.)	95
Clifton Precision Products Co., Inc.	97
Comar Electric Co.	96
Connecticut Hard Rubber Co.	89, 98
Consolidated Electrodynamics Corp.	29
Continental Connector Corp. (Div. of DeJur-Amsco Corp.)	4
Control Switch Div. (Controls Co. of America)	93
Daven Co., The	59
Dynamic Gear Co., Inc.	36
Eastern Air Devices	37
Edcliff Instruments	39
Edison, Thomas A., Industries	11
Electrical Industries	27
Electroid Corp.	21
Electro-Mec Laboratory, Inc.	18
Elgin National Watch (Abrasives Div.)	36
Ellis & Watts Products, Inc.	83
Engelhard Industries, Inc.	8, 9
Graphic Systems	20, 41
Guardian Electric Manufacturing Co.	46
Handley, Inc.	53
Hart Manufacturing Co.	28
Haydon Switch, Inc.	32
Heinemann Electric Co.	55
Heinze Electric Co.	76
IMC Magnetics Corp.	72
Indiana General Corp.	44
Industrial Research	47
Instrument Development Labs, Inc.	80
Kearfott Div. (General Precision, Inc.)	67, 69, 71, 73
Kinney Vacuum Div. (The New York Air Brake Co.)	3

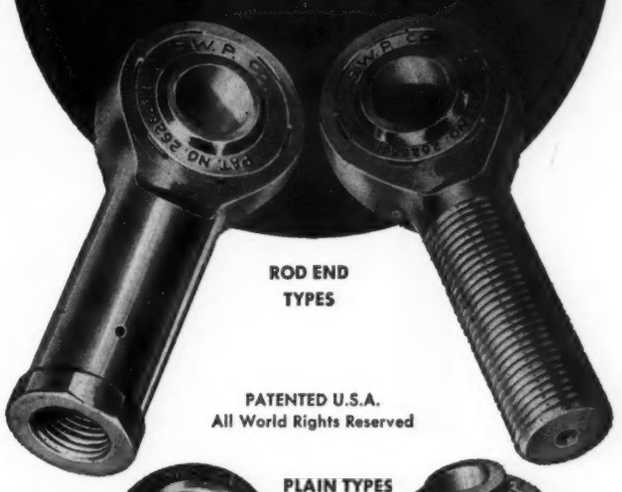
ADVERTISERS' INDEX

ADVERTISERS	Page Number
Librascope (Div. General Precision, Inc.)	Cover 2
Litton Industries	81
Magnavox Co., The	10
Martin, H. S. & Sons, Co.	38
Mepco, Inc.	94
Mosinee Paper Mills Co.	20
Muirhead & Co., Ltd.	74
National Pneumatic Co., Inc.	70
New York Air Brake Co., The	3
Newark Electronics Corp.	81
Non-linear Systems, Inc.	32
North Atlantic Industries, Inc.	75, 86
Northfield Precision Instrument Corp.	79
Ohio Carbon Co.	58
Pic Design Corp.	84
Raytheon Co. (Equipment Div.)	6
Reeves Instrument Corp.	40
Reflectone Electronics, Inc.	92
Republic Aviation Corp.	45
Sel-Rex Corp.	89
Skinner Chuck Co., The (Skinner Electric Valve Div.)	65, 66
Skydyne, Inc.	5
Slip Ring Co. of America	26
Sorensen & Co., Inc.	51
Southwest Products Co.	91
Split Ballbearing (Div. MPB)	82
Staedtler, J. S., Inc.	Cover 3
Standard Plastics Co., Inc.	80
Stanpat Co.	25
Sturtevant, P. A., Co.	58
Trak Electronics Co. (Div. of CGS Labs, Inc.)	41
Unimax Switch (Div. of The W. L. Maxson Corp.)	23
United Aircraft Corp. (Norden Div.—Ketay Dept.)	19
United Aircraft Corp. (Norden Div.—Milford Dept.)	30
United Electric Controls Co.	90
Vapor Heating Corp. (Vap-Air Aeronautical Products Div.)	33
Veeder-Root, Inc.	38
Victory Engineering Corp.	98
Wurlitzer Co., The	87
Yardney Electric Corp.	24, 78

SOUTHWEST

"Monoball"®

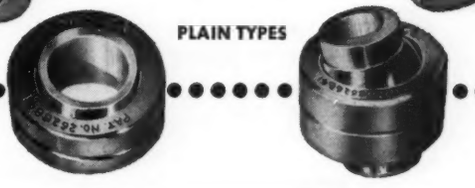
SELF-ALIGNING BEARINGS



ROD END TYPES

PATENTED U.S.A.
All World Rights Reserved

PLAIN TYPES



CHARACTERISTICS

	ANALYSIS	RECOMMENDED USE
1	Stainless Steel Ball and Race	For types operating under high temperature (800-1200 degrees F.).
2	Chrome Alloy Steel Ball and Race	For types operating under high radial ultimate loads (3000-893,000 lbs.).
3	Bronze Race and Chrome Steel Ball	For types operating under normal loads with minimum friction requirements.

Thousands in use. Backed by years of service life. Wide variety of Plain Types in bore sizes 3/16″ to 6″ Dia. Rod end types in similar size range with externally or internally threaded shanks. Our Engineers welcome an opportunity of studying individual requirements and prescribing a type or types which will serve under your demanding conditions. Southwest can design special types to fit individual specifications. As a result of thorough study of different operating conditions, various steel alloys have been used to meet specific needs. Write for Engineering Manual No. 551. Address Dept. EMD-60

SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

CIRCLE NO. 81 ON INQUIRY CARD

REFLECTONE

miniature *PM* motors

fit in very little space

perform in a

BIG WAY

in portable recorders and dictating equipment. Only ⅞" dia. — under 2½ oz. — high torque — low power drain — unexcellent reliability. To your specifications: mountings, shafts, bearings, integral gearing, governed or not, 4-30 vdc, rpm to 20,000

REFLECTONE ELECTRONICS, INC.

POST ROAD • STAMFORD, CONN.

CIRCLE NO. 82 ON INQUIRY CARD

For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

A-C Digital Conditioning 218

The design of a new carrier system provides an extremely reliable means of conditioning the output of reluctance-type transducers for recording and/or control applications. The high output and low impedance associated with variable-reluctance systems make them ideally suited for applications where high humidity contributes to the deterioration of high impedance circuits. Modular construction, a variety of options within the components, and special control units permit arrangements to meet virtually any instrumentation requirement from a single 2-channel configuration to a multi-channel system. Brochure gives design principles and specifications. Wiancko Engineering Co., Pasadena, Cal.

Logic Elements 145

An integrated line of encapsulated logic elements for 100 kc. operation have been fully proved in applications where reliability is of prime importance. Data sheets containing specifications, schematics and case drawings are available. C & K Components, Inc., Newton, Mass.

Analog Computers 220

4 page brochure describes a line of general and special purpose analog computers and accessories. Included are descriptions and specifications of a precision master analog computer (80 operational amplifiers); process master analog computer (120 operational amplifiers); electronic multiplier; XY—data plotting boards; linear programming computers and missile range instrumentation computers. Also described is an advance computed system that incorporates the iterative capability of digital computers while maintaining the speed and ease of use of analogs. Computer Systems, Inc., N.Y., N.Y.

Logic Switches 138

A complete line of electro-mechanical logic switches and decimal counters, all featuring a common means of communications, are well-suited for use in large and small data systems. The logic switches feature fixed state stability, short term response delay, reliable operate and drop-out times and complete separation of switching elements. Brochure covers operating principles, design features and specifications. Tally Register Corp., Seattle, Washington.

Molybdenum Metal 126

Bulletin provides convenient, condensed data and selected references on binary and more complex diagrams pertaining to molybdenum. The new publication points to constitution diagrams as aids, not only in molybdenum alloy research, but also in choosing barrier layers in cladding, selecting filler metals in brazing, and predicting possible corrosion under certain conditions. Each system is covered in a brief summary of the present state of knowledge followed by a set of references from a wide range of technical publications containing details of research. Climax Molybdenum Co., Div., of American Metal Climax, Inc., N. Y., N. Y.

Pressure Transducers 13

Specification sheets describe a line of pressure transducers that feature long li and reliability, precision phasing, hi accuracy and linearity under environmenta conditions of shock, vibration, wide tem perature ranges, humidity, or corrosio Edcliff Instr., Monrovia, Cal.

Paper-Dielectric Capacitors 14

A complete line of flat and round, mol miniature, paper-dielectric capacitors a claimed to be the smallest paper-dielectri capacitors manufactured. They are esp cially suited for the close stacking a assembly requirements of miniature ele tronic devices. The units are non-indu tively wound with highest grade condense kraft paper (not metallized paper), an then thoroughly impregnated. The lea are securely anchored to the capacitor bo The capacitance values range from .00 mfds. to 10.0 mfds. Working voltages ran from 75 volts to 1000 volts. Operati temperatures range from —55°C to +100° without derating. Complete details, eng neering data and free samples are ava able. Capcon, Inc., New York, N. Y.

Pinion Combinations 13

Designers can select from hundreds of lo cost zinc die cast, one-piece gear a pinion combinations to solve transmissi problems involving small, lightload gea ing. This low-cost service, made possi by an interchangeable unit die system the subject of a 10-page catalog. Repr sentative combinations include: gear a pinion (with hole or shaft); flanged pini (with hole or shaft); cup gear and pini (with hole or shaft); plus gears and pinio with special features. For special applic tions, parts can be molded in Delrin, nyl and most thermoplastics. Gries Reproduc Corp., New Rochelle, N. Y.

Adjustable Time Delays 14

Time delay relays incorporating an exc sive no-moving-parts, solid state timi module, feature adjustable timing that pr vides maximum "on-the-spot" flexibil They are said to be the first adjusta time delay devices that meet all t accuracy and reliability requirements high performance military and industr electronic systems. The timing adjustm is made by a simple, quick change of external resistance value. An 8-p bulletin includes a comprehensive descr tion of circuit design and complete standa and special type specifications. Tw Instrument, Inc., Hicksville, N. Y.

Instrument Translators 12

Included in a 2-page bulletin are descr tions and specifications of 2 instrum translators. These units are subminia carrier systems used with ac transduc potentiometers and some bridge-t strain gage transducers in systems hav a 28 volt dc power supply and requiri dc output signal. The models are built meet the rugged requirements of airbo use. Crescent Engineering & Research C El Monte, Calif.

Whether Congress would be along with giving the President this authority, however, is not certain.

MAJOR MERGER IN SWITCH INDUSTRY

Controls Company of America Merges Hetherington Div. With Electrosnap Corp. to form New Control Switch Division.

One of the precision switch industry's most complete product lines has come into existence with the announcement by Louis Putze, President of Controls Company of America, Schiller Park, Ill., that its subsidiary Hetherington, Inc., has been merged with Electrosnap Corporation, Chicago. The Electrosnap organization was recently merged with Controls Company of America.

"This merger is important to switch users", Mr. Putze stated, "because it combines two major manufacturers of panel switches, indicator lights and limit switches for military and industrial applications into a single source of supply.

"Now, customers need deal with just one sales engineer instead of two. Three plant locations—Folcroft, Pa., Chicago, Ill. and El Segundo, Calif.—will provide regional engineering and manufacturing facilities to speed up delivery and service.

"The combination of military and industrial experience will enable the new Division to expand its activities in areas such as human factors, sub-sub-miniaturization, image displays and controls for special environments.

"Local sales offices with factory-trained personnel have been set up to provide on-the-spot application engineering. An expanded nation-wide distributor organization will assure our customers of immediate delivery from local sources," Mr. Putze said.

...nges in Stockholdings

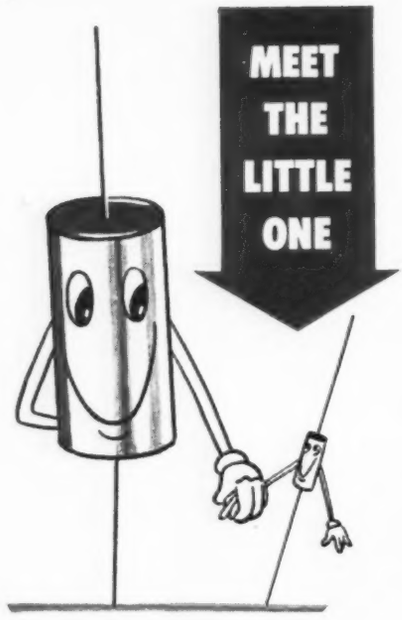
...large stockholders

ELECTROSNAP
HETHERINGTON

CONTROL SWITCH DIVISION

CONTROLS COMPANY OF AMERICA
4218 W. Lake Street • Chicago 24, Illinois
Telephone: VAn Buren 6-3100 • TWX No. CG-1400

CIRCLE NO. 83 ON INQUIRY CARD



C-1H

Twice Size

MEPCO Carbon Film

MICRO-MINIATURE . . . solder sealed in high-density alumina case.

MEPCO Type C-1H Carbon Film Resistors measure only .250" in Length by .120" Diameter, with a .1 Watt rating at 70°C. It's a "natural" for printed circuits that must perform in extreme environmental conditions.

Also available with resin coat, **MEPCO** Type C-1 which is 15/64" Long, by 5/64" OD.

MEPCO INC.
MORRISTOWN, N. J.

CIRCLE NO. 84 ON INQUIRY CARD

For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

Wafer Capacitors 185

Four-page data sheets describe tiny glass-dielectric wafer capacitors that are ideally suited for printed circuit, modular or encapsulated assemblies requiring high reliability. The items are said to be the smallest high stability capacitors currently available. Because dielectric and conductor layers are sealed together at high temperatures and pressure, they will operate under high heat and humidity environments without further encasing. Corning Glass Works, Corning, N. Y.

Servomechanisms 212

Described are a complete line of predesigned mechanisms and components for the servo and instrument fields. An unlimited variety of geared mechanisms for use in breadboarding may be assembled from the instructions in a 6-page bulletin. Precision Mechanism Corp., East Meadow, N.Y.

Noble Metal Thermoelements 148

To assist users in selecting materials best suited for their purposes, a brochure provides data on the wide range of noble metal thermoelements. Temperature-millivolt curves are given for the various thermocouple materials along with comparisons to certain non-noble combinations. Engelhard Industries, Inc., Newark, N. J.

Servo Analysis 186

New servo design report explains application of a servo system simulator, called Servolab, to the design of a wide variety of control systems. Step by step, the report describes how this highly versatile synthesis and analysis system is used to solve complex servo problems quickly. The dynamic characteristics of control systems and feedback loops are simulated, demonstrated, displayed, and completely analyzed. The entire system or any portion can be put through its paces. Servo Corp. of America, Hicksville, N. Y.

Silicon Zener Diodes 193

A six-page catalog describes a complete line of hermetically sealed silicon zener diodes, including listings of 152 standard types, and instructions on selection from 1584 standard and special voltage tolerance types. Also detailed are zener diode performance characteristics, current limits and derating curves. International Rectifier Corp., El Segundo, Cal.

FHP Motors 19

4 page bulletin contains a technical artic on the speed control of fractional horse power motors. Also included are discussion on the motors' applications to high spe oscillographic recorders and an automat telephone exchange. Bodine Electric C Chicago, Ill.

High Vacuum Pumps 21

Exclusive, compact all-metal couplin with swivel flanges and a rugged, unitiz internal structure are only 2 importa features of electronic high vacuum pump Data sheet describes the high-vacuu pump together with corresponding pow supply which operates the units. A cal bration curve is included with pump cu rent plotted against pumping pressure Ultek Corp., Palo Alto, Cal.

Automatic Checkout Equipment 18

4-page brochure describes four new aut matic checkout units: an rms-to-dc co verter; a voltage-to-digital converter; timer-counter and a digital printer. T units meet the rigid environmental re quirements of MIL-E-4158B and are us in a missile automatic checkout syste that measures dc voltages, ac voltage and the transient responses of servo which control time, frequency, rat thrust, roll, pitch and yaw. Epsco, Inc Cambridge, Mass.

Recording Oscillograph 19

A 16-page brochure includes complete d scription of an 18 or 26 channel oscil graph, evaluation of dynamic testing, d scription of a rapid-access magazine an other accessories, and a table of specifica tions for galvano-meters. The oscillograp records simultaneously as many as 18 26 separate items of test data and permi the study of phenomena in their relation ship to a common time base and to ea other. Consolidated Electrodynamics Cor Pasadena, Cal.

Size 11 Servomotors 20

A 16 page catalog outlines electrical an mechanical specifications of a line of si 11 servomotors, and shows individual sch matics as well as torque-speed curv Units described include 115 volt, 400-cy servomotors, adjustable velocity-damp an inertia-damp servomotors, and servomot rate generators. Helipot Div., Beckm Instruments, Inc., Fullerton, Cal.

CORRECTION:

This motor generator was reported in the February issue to have an output variation of ±4%, obviously a poor parameter for any integrating motor generator, whereas the correct value, ±0.4%, is a very low output variation.

Integrating Motor Generator 20

Said to be the smallest unit of its type cu rently available, a servo motor integra generator is thermistor compensated a characterized by an input of .5v/1000 rp linearity of .06% from 0-3600 rpm, and o put variation from temperature (−15° C +75°C) of ±0.4% from the value at 25 Complete design data given. Kearfott C Inc., Little Falls, N. J.

Over a million ceramic pieces...

DAILY!

Centralab's enormous facilities for ceramic production can serve your company, too!

1,215,000 ceramic pieces are produced in an average day at CENTRALAB! Some are big, some are small. Some require exacting tolerances and intricate machining; others are less complex, but still require appropriate facilities for quantity production.

The CENTRALAB Ceramic Design Handbook is available for your use. Write for your copy, or consult Sweet's Product Design File (folio 4a/ce).

SOME STATISTICS ON CENTRALAB'S FACILITIES

29 Kilns
A variety of linear, circular, and oven types, in a comprehensive range of sizes to meet any need.

85 Presses
Specialized equipment for forming, extruding, pelleting.

175 Precision Machines
Equipment for grinding, polishing, boring, threading, etc. to tolerances ±.0002".

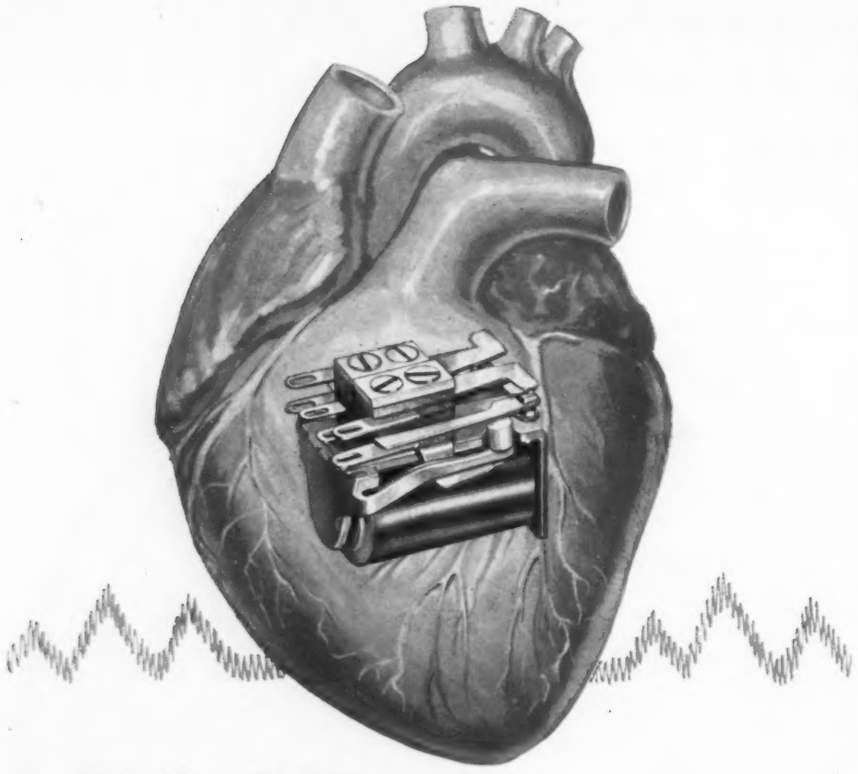
226,600 sq. ft. of floor space
devoted to ceramic engineering and production.

Centralab
CRL
X-6009

The Electronics Division of Globe-Union Inc.
924D E. Keefe Avenue • Milwaukee 1, Wisconsin
In Canada: P. O. Box 400, Ajax, Ontario

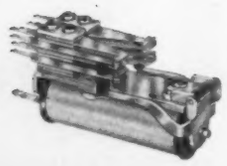
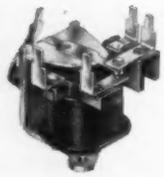
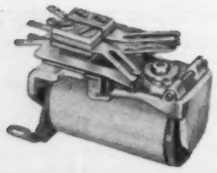
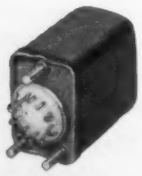
ELECTRONIC SWITCHES • VARIABLE RESISTORS • CERAMIC CAPACITORS • PACKAGED ELECTRONIC CIRCUITS • ENGINEERED CERAMICS

CIRCLE NO. 85 ON INQUIRY CARD



a GOOD one is important!

• Relays are often referred to as the heart of an electronic control circuit. A good one is essential to efficient performance and longer life. For years Comar has aided manufacturers suffering from relay trouble.

Our relay technicians will show you how to put more vim and vigor in your relay circuits. Send the symptoms... we'll recommend the cure...no obligation.

comar electric

3349 ADDISON STREET, CHICAGO 18, ILLINOIS

RELAYS • SOLENOIDS • COILS • SWITCHES • HERMETIC SEALING

CIRCLE NO. 86 ON INQUIRY CARD

Power Supplies 139

Bulletin describes a line of transistorized precise regulation power supplies; a portable series, plug-in models, and a system-engineered sealed series. Two instruments for the accurate measurement of resistance in the ultra high megohm range with accessories for measuring volume resistivity at elevated temperatures are also described, as well as a wide range ohmmeter and an automatic relay tester. Mid-Eastern Electronics Inc., Springfield, N. J.

Magnetic Recording Heads 139

A new 4-page bulletin lists specifications and mounting arrangements of approximately sixty different designs of precision magnetic recording heads. Applied Magnetics Corp., Goleta, Cal.

Laminated Plastics, Vulcanized Fibre 203

Basic application information and engineering data on laminated plastics and vulcanized fibre contained in a new condensed catalog provides an aid to engineers in selecting and applying these basic materials for electrical, electronic and mechanical components. Taylor Fibre Co. Norristown, Pa.

Snap Switch Relay 139

Specifications and dimensional drawings of a snap switch relay will be of particular interest to engineers seeking an ideal device for controlling inductive loads. The compact designed, ruggedly constructed relay features solenoid operated, multiple contact snap action. Warco Industries St. Louis, Mo.

Synchro Components 139

A reference data brochure on Size 1 synchro components contains general electrical specifications for torque receivers, torque transmitters, control transformers, resolver transmitters, vector resolvers, linear transformers, and control differentials. The design options and mechanical characteristics are also listed. All units meet mil specs. Induction Motors of Calif., Maywood, Calif.

Magnetic Shielding 167

Data sheet explains how custom-built magnetic shield enclosures simplify the evaluation of test data. The units eliminate factors introduced by magnetic fields normally radiated by vibration exciter units. Magnetic Shield Div., Perfection Mica Co., Chicago, Ill.

Anti-Statics 181

Design engineers working with thermoplastics, thermosets, polyethylenes, as well as other synthetic fibres, will be interested in two new anti-statics described in a data sheet. Anti-static #79 makes such plastics as polystyrenes, styrenes, and vinyls static-free and dust-free semi-permanently from one single application while permanent de-staticizing is possible on ployethylenes with one single application of anti-static #79-OL. Merix Chemical Co., Chicago, Ill.

Slit Electrical Insulation 17

A new 4-page bulletin covers many kinds of precision-slit electrical insulation. Tables list ten popular slit plastic films, papers and combinations as well as thicknesses, widths, tolerances, and coil and core sizes in which each is supplied. Handy conversion tables are included to enable users to translate area to lineal feet per pound. Inmanco Division of Insulation Manufacturers Corp., Chicago, Illinois.

Fasteners 149

17 case histories in a brochure describe assembly savings achieved in various industries through the use of fasteners from a selection of more than 9000 variations. Tinnerman Products, Inc., Cleveland, Ohio.

Rotary Solenoids 207

Brochure describes standard and special solenoids, packaged switch assemblies and [illegible] drive stepping units. Engineering specifications, advantages of these units and their applications are included. Pacsol Div., Illinois Tool Works, Hawthorne, Cal.

Versatile Plugs 101

Design of plugs makes them easily adaptable to many configurations. Hermaphrodite contacts and insulators fit both plugs and receptacles. Cannon Electric Co., Los Angeles, Cal.

Miniature Clutches 140

Data on a line of electro-magnetic clutches and brakes that are ideal for multi-speed devices, direction changers and machine tool controls where small size, light weight, fast response, high torque and low cost are the design criteria. Autotronics, Inc., Florissant, Missouri.

Remote Control 182

Basic engineering data is given on a completely closed, hydraulic system for remote motion control or duplication. Included are features, dimensions, accessories, uses, and installation information. Hydronic Corp., Detroit, Mich.

Snap-acting Switches 147

To satisfy a wide variety of assembly requirements, subminiature precision snap-acting switches have three kinds of soldering terminals, as well as snap-on terminals and terminals for printed-circuit wiring. Data sheet gives details of the switches with five terminal styles. W. L. Maxson Corp., Wallingford, Conn.

High Voltage Transistors 174

High voltage NPN and PNP germanium alloy junction transistors recommended where large dynamic range is desired and large voltage swings required are presented in an 8-page brochure. Complete specifications, application circuitry and characteristic curves and graphs are included. General Transistor Corp., Jamaica, N. Y.

Clips And Terminals 219

Catalog sheet and sample kits are available on a wide variety of spring and fuse clips and lock washer terminals. The new lock washer terminals are manufactured for #4, #6, and #8 holes from .018 brass or phosphor bronze, hot tinned. Zierick Mfg. Corp., New Rochelle, N.Y.

Panel Indicator Lights 137

Sixteen page catalog describes large legend, lighting word lights that will accomodate up to three rows of .125" high characters, seven per row. Standardized line offers instantaneous indication, maximum reliability, mil spec qualification, rebulbing from the front without tools and removable lenses. Master Specialties Co., L. A., Calif.

Silicon Diodes 208

New semiconductor applications report, "Applying Thermal Characteristics of Silicon Diodes," discusses thermal characteristics of forward biased diodes as low voltage reference devices, temperature compensated (voltage reference) diodes, effect of thermal resistance and thermal film resistants in forward and Zener diodes. Transitron Electr. Corp., El Monte, Cal.

Vibration Test Systems 150

System performance, components and accessories are covered in a 4-page bulletin on vibration test systems. A complete description and dimensions of a 400 lb. force shaker is given along with a control console. Unholtz-Dickie Corp., Hamden, Conn.

Miniature Motor-Generator 151

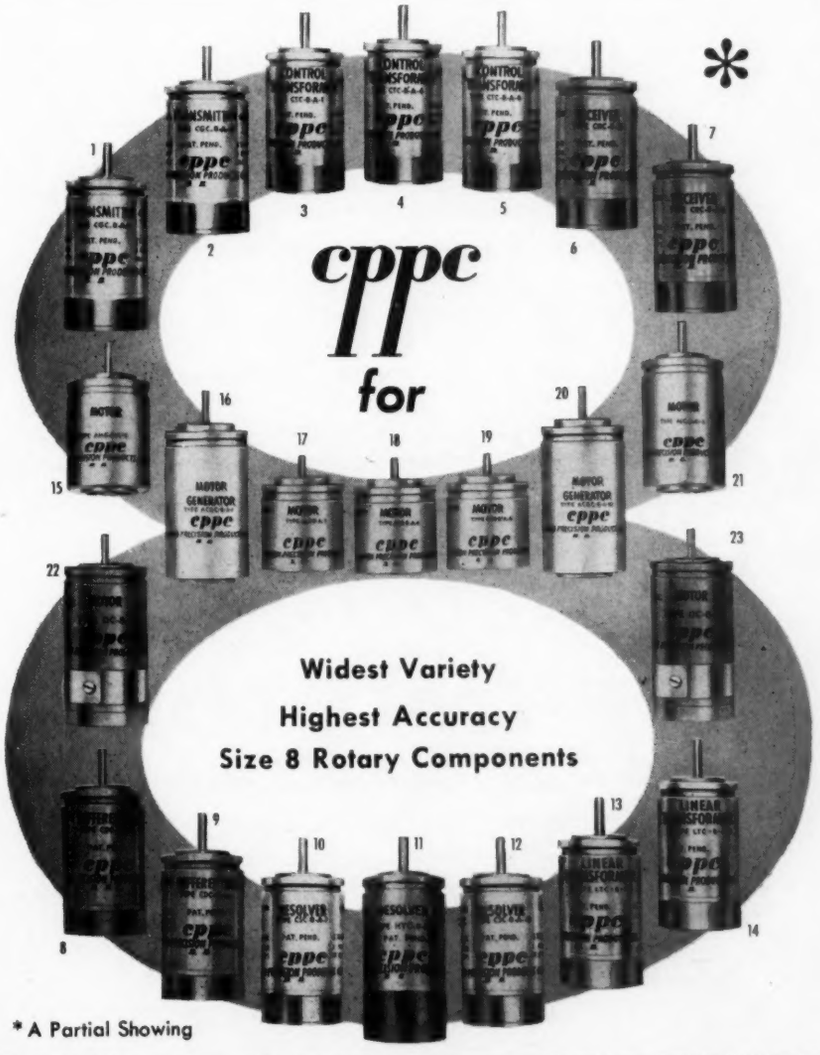
A two-page technical bulletin provides detailed performance data and design specifications on a new miniature motor-generator unit. The unit consists of a low-inertia control motor (geared or direct output) and a 10v/1000 rpm a-c drag-cup rate generator and is designed for precision instrument applications requiring a compact and commercially priced device. Bulletin includes motor speed-torque and speed-voltage curves, complete dimensions and electrical characteristics. Holtzer-Cabot Motor Div., National Pneumatic Co., Inc., Boston, Mass.

Millimicrosecond Quantizer 175

Bulletin describes the operational characteristics and technical specifications of a quantizer, a transistorized chronograph that converts varying time intervals into digital coded signals. No averaging is done, each time interval is measured to a resolution of 20 millimicroseconds with an accuracy of 1 part in 10^7 per day. Computer Equipment Corp., Los Angeles, Cal.

Missile Batteries 205

Eight-page bulletin describes the Silvercel battery system in general, and lists specific data for a new Silvercel automatically activated primary battery and two new rechargeable batteries. Data listed include electrical, physical, environmental and typical application characteristics as well as discharge curves. The miniature batteries offer power capabilities five to six times greater than other batteries of equal size and weight. Yardney Electric Corp., New York, N.Y.



* A Partial Showing

Clifton Precision's size 8 rotary components have been tried and proven by customers over the past 4 years. More than 50,000 have been shipped. These are the most accurate and best tested (because they are use tested) size 8 rotary components on the market today.

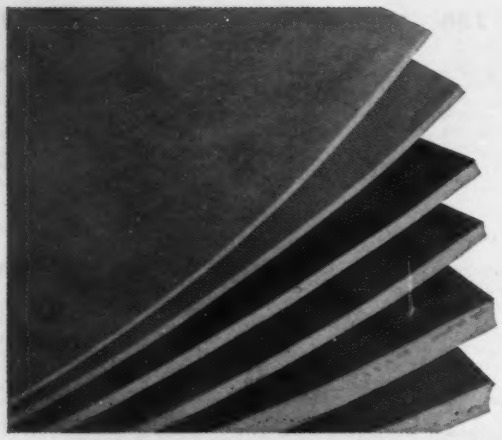
1. Torque transmitter (26v. input) 2. Torque transmitter (115v. input) 3. Control transformer (lo Z) 4. Control transformer (hi Z) 5. Control transformer (very hi Z) 6. Torque receiver (26v. input) 7. Torque receiver (115v. input) 8. Torque differential (lo Z) 9. Torque differential (hi Z) 10. Electrical resolver (.5 t.r.) 11. Precision computing resolver (feedback winding) 12. Electrical resolver (1 t.r.) 13. Linear transformer (115v. input) 14. Linear transformer (26v. input) 15. Servo motor (1" length, .40 in-oz stall torque) 16. Motor generator (10v. input) 17. Servo motor (53/64" long) 18. Servo motor (35v. center tap) 19. Servo motor (26v. center tap) 20. Motor generator (26v. input) 21. Servo motor (.30 in-oz stall torque) 22. D.C. motor (14v. input) 23. D.C. motor (28v. input)

CLIFTON PRECISION PRODUCTS CO., INC.
CLIFTON HEIGHTS, PA.

cppc

Sales Office: 9014 W. Chester Pike, Upper Darby, Pa.—Hilltop 9-1200, TWX Flanders, Pa. 1122

CIRCLE NO. 87 ON INQUIRY CARD



SILICONE SPONGE RUBBER SHEETS

Flexible temperature range -100°F to 500°F

COHRlastic R-10470 silicone sponge rubber sheets have a dense, uniform, non-absorbing closed cell structure highly suitable for soft gasketing, vibration dampening, fairing strips, pads, cushions and other applications where resiliency at extreme temperatures is required. It may be bonded to metals, plastics, fabrics or silicone rubber. COHRlastic R-10470 possesses superior compression set resistance, excellent dielectric properties, immunity to aging, ozone and weather hardening. Meets many specifications.

AVAILABLE FROM STOCK: in 12" x 12" sheets and 24" x 24" sheets — 1/16" through 1/2". Special thicknesses and sheet sizes up to 30" x 30" and 24" x 48" made to order. Sold nationally through distributors.

FREE SAMPLE and folder — write, phone or use inquiry service.

Leader in Fabrication of Silicone Rubber Products

CHR **CONNECTICUT HARD RUBBER CO.**

Main office: New Haven 9, Connecticut

CIRCLE NO. 88 ON INQUIRY CARD

VECO T.M. *HI-reliability*

THERMISTORS

VECO *is the* ***approved*** *source for leading missile manufacturers*

Remember, HI-RELIABILITY, comes only from experience and know-how and VECO has years of manufacturing and design experience in solid state electronics, a seasoned staff of engineers and a rigid quality control system.

HI-RELIABILITY is yours for the asking—write for the VECO Technical Catalog with data on more than 650 stock items—Manufactured to MIL-9-5923 and other applicable MIL standards.

VECO glass enclosed thermistors are not adversely affected by radiation.

VECO also manufactures varistors, electronic controls, gas analysis cells, combustion analyzers, electronic and thermal instruments, medical and biological instrumentation and temperature sensing devices.

Cataloged in EEM Sec. 4700 and Radio Master

VECO VICTORY ENGINEERING CORPORATION

120 Springfield Road, Union, N. J.
MUrdock 8-7150

CIRCLE NO. 89 ON INQUIRY CARD

Ceramic Capacitors

Data is presented on non-metallic encased tubular mylar and metallized mylar capacitors that feature: low dissipation factor less than 1% at 25°C; high insulation resistance, greater than 10,000 to 20,000 megohms per mfd. at 25°C; capacitance tolerance, standard is ±20%, tolerances available, to ±2%; test voltage, 1¼ and 2 x rated voltage for 1 minute at 25°C; temperature range, —60°C to +125°C without derating, up to 150°C in certain applications with proper derating; windings: non-inductive, suitable for RF applications. Potter Co., North Chicago, Illinois.

Rotary Solenoids

Two new engineering data sheets describe an "F" size, 300 inch-pound-degree and a "C" size, 70 inch-pound-degree rotary solenoid. Each of these standard units are designed to meet military and government specifications. The units are also available in packaged adaptations complete with switching elements or other mechanical attachments. The data sheets contain complete information on solenoid torque characteristics, direction of travel, voltage requirements, duty cycles, stroke in degrees, ambient temperatures and include engineering drawings and torque charts. Pacific Div., Illinois Tool Works, Hawthorne, Cal.

Environmental Test Chambers

A brochure describes features and capabilities of walk-in space chambers. These huge chambers include a variety of specifications for the simulation of extreme conditions of space, such as altitudes to 1 million feet, temperatures from —150° to +2000°F, humidity to 95%, rainfall to 5 inches per hour, ram air flow, variable altitude climb and dive rates, solar radiation to 140 watts per sq. ft., radiant heat assemblies, dissipation of live or static loads and vibration accommodation. Tenney Engineering, Inc., Union, N. J.

Flameproof Plastics

Seven new flame-proofed and heat resistant diallyl phthalate plastic molding compounds for electrical and electronic use are detailed in a four-page spec sheet with brief descriptions of each and recommended applications. Mesa Plastics Co., L. A., Cal.

Hi-Temp Laminates

Bulletin describes 2 high-temp industrial laminated plastics for use at temperatures up to 500°F. Both types are available in tube form for special requirements. Synthane Corp., Glendale, Cal.

Coax Connectors

Electrical, mechanical and environmental specs on micro-miniature, snap-locking coaxial connectors are included in a catalog that also describes a variety of plugs, receptacles, caps and adapters in 50, 75 and 95 ohm impedances. Connectors exhibit fast, easy positive connection; maximum resistance to shock and vibration and high reliability. Electro-Physics Laboratories, Monrovia, Cal.

Thermal Insulation

Min-Klad Interlok, a newly developed insulation system, combines low heat conductivity, low diffusivity, high temperature resistance, resistance to erosion, and high structural strength. Thermal conductivity is actually lower than the molecular conductivity of still air. Surfaces and the insulating core are bonded together in a variety of techniques to form an integral, structurally strong unit. Data sheets describing specific applications are available. Johns-Manville Corp., New York, N. Y.